INTERNATIONAL COURT OF JUSTICE

DISPUTE CONCERNING THE CONSTRUCTION OF A ROAD IN COSTA RICA ALONG THE SAN JUAN RIVER

NICARAGUA *v.* COSTA RICA

COUNTER-MEMORIAL OF COSTA RICA

VOLUME II

ANNEXES 1 - 10

19 DECEMBER 2013

LIST OF ANNEXES

VOLUME II

TECHNICAL AND ENVIROMENTAL REPORTS

No.	DOCUMENT	Pag
1	University of Costa Rica Centre for Research in Sustainable Development, Department of Civil Engineering, Report on Systematic Field monitoring of Erosion and Sediment Yield along Route 1856, September 2013	1
2	Comisión de Desarrollo Forestal de San Carlos (CODEFORSA), Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road, Report of Activities to the Ministry of Foreign Affairs of the Republic of Costa Rica, January 2013 English Translation	29
3	Allan Astorga G. and Andreas Mende, Route 1856: Analysis of the Change in Land use Based on Satellite Images Before and After the Construction of the Border Road, August 2013	103
4	Costa Rican Institute of Electricity (ICE), SBU Projects and Associated Services, Centre for Basic Engineering Studies, Department of Hydrology, Report on Hydrology and Sediments for the Costa Rican River Basins draining to the San Juan River, August 2013	133
5	Andreas Mende, with Allan Astorga G. and Olivier Chassot, Border Road No 1856 – Evaluation of the 54 Sites of Purported Direct Sediment Delivery mentioned by Ph.D. Mathias Kondolf, September 2013	291

6	Dr. Andreas Mende and Dr. Allan Astorga, Inventory of Slopes and Water Courses related to the Border Road Nº 1856 between Mojón II and Delta Costa Rica, September 2013	369
7	Report from Ana Lorena Guevara Fernández, Vice-Minister of the Environment, Costa Rica, to Enrique Castillo Barrantes, Minister of Foreign Affairs, Costa Rica, Reference DVM-293-2013, 8 October 2013 English Translation	409
8	Consejo Nacional de Vialidad (CONAVI), Program for the Consolidation and Continued Improvement of Route No 1856, Reference DIE-02-13-3107, 25 October 2013 English Translation	421
9	Professor Colin Thorne, Report on the Risk of Irreversible Harm to the Río San Juan relating to the Construction of the Border Road in Costa Rica, 4 November 2013	453
10	Costa Rica, Centro Científico Tropical, Environmental Diagnostic Assessment (EDA), Route 1856 Project – Ecological Component, November 2013	499

ANNEX 1

University of Costa Rica Centre for Research in Sustainable Development

Department of Civil Engineering

Report on Systematic Field monitoring of Erosion and Sediment Yield along Route 1856

September 2013

UNIVERSIDAD DE COSTA RICA
FACULTAD DE INGENIERÍA
ESCUELA DE INGENIERÍA CIVIL

CENTRO DE INVESTIGACIONES EN DESARROLLO SOSTENIBLE
CIEDES

Report on Systematic Field monitoring of Erosion and Sediment Yield along Route 1856

By:
Eng. Rafael Oreamuno Vega, M. Eng.
Roberto Villalobos Herrera

September, 2013

This document has been prepared by personnel of the Universidad de Costa Rica's Centre for Research in Sustainable Development (known as CIEDES in Spanish) under the direction of Eng. Rafael Oreamuno, according to the allocation of responsibilities shown below.

Field work:
Carlos Aguilar, Rafael Oreamuno, and Roberto Villalobos.

Sediment sample processing:
Mauricio Mendoza, and Luis Diego Ramírez.

Analyses and elaboration of the Report:
Rafael Oreamuno, and Roberto Villalobos.

Administrative officer of CIEDES:
Marco Arias, MPA.

Eng. Rafael Oreamuno, M. Eng.is a professional civil engineer registered in Costa Rica's Colegio Federado de Ingenieros y Arquitectos (license number IC-2423) and Professor of the Department of Civil Engineering at the Universidad de Costa Rica since 1987, private consultant, he currently holds the office of Director of CIEDES. His degrees are:

- Licenciado en Ingeniería Civil from the Universidad de Costa Rica, 1980.
- Master of Engineering in River Engineering and Hydrology from the University of New Brunswick, Canada, 1983.

Marco Arias, MPA is the administrative officer at CIEDES; as such he has coordinated the logistics and transport for all visits.

Carlos Aguilar, Mauricio Mendoza, Luis Diego Ramírez and Roberto Villalobos are senior year Civil Engineering students at the Universidad de Costa Rica which work as Assistants for CIEDES. All have soil laboratory experience as part of the standard Civil Engineering Programme. The Civil Engineering programme at the Universidad de Costa Rica is deemed as Substantially Equivalent by the Canadian Engineering Accreditation Board. The Substantially Equivalent Accreditation means that the Civil

Engineering Program of the Universidad de Costa Rica complies with all the international standards, defined in the Washington Agreement, for the education of civil engineers.

UNIVERSIDAD DE COSTA RICA

CIEDES
Centro de Investigaciones en Desarrollo Sostenible

Contents Table

Introduction 1
Sediment yield estimation 3
Sheet erosion 3
Cut slope erosion 4
Road fill slope erosion 5
Rills 6
Sediment size distribution and classification 9
Cut slope 9
Sediment trap #2 10
Sediment trap #3 11
Sediment trap #4 12
Summary of Sediment Size and Limit Results 13
Contrasts between Landslide and Gully erosion Forms, Triggers and Processes 14
Landslides 14
Gullies 14
Contrasts between Landslide and Gully erosion 15
Conclusions 16
Bibliography 19
Annex I – Sediment trap #2 configuration 20

Introduction

The Universidad de Costa Rica's Centre for Research in Sustainable Development (known as CIEDES in Spanish) has been asked to assess the average annual erosion rate and the average erosion depths from the road bed, cut slopes, and fill slopes on Costa Rica's Route 1856. In order to provide this assessment, a series of sites have been monitored by CIEDES' personnel between 8 June and 17 August 2013. These sites include the two largest rotational landslides and three erosion gullies found in the stretch of road extending from Boundary Marker II to the Infiernito River (referred to as the study area), as well as a sediment trap which collects material from cut slopes which only show evidence of sheet erosion, and a slope which displayed most intense rill formation. The location of each site is indicated in Figure 1.

In preparing this Report, we have reviewed the Report prepared by G. Mathias Kondolf entitled "Environmental Impacts of Juan Rafael Mora Porras Route 1856, Costa Rica, on the Rio San Juan, Nicaragua", December 2012, Annex 1 to Nicaragua's Memorial in *Construction of a Road* case (the ***Kondolf Report***).

Weather conditions (listed on Table 1) varied between all five visits as the rainy season in the region became more established. The first two visits took place during fair conditions with partly cloudy skies. During the first visit, there was a brief, albeit intense rain shower. The third and fourth visits, in July and August, took place during much heavier cloud cover and rainfall, with a constant drizzle interrupted by heavy showers on both days. Weather conditions during the final visit were sunny and dry, and the soil was visibly dry.

Table 1. Site visit dates and weather conditions.

Visit number	Date	Weather conditions
1	June 8th, 2013	Partly cloudy, single shower
2	June 23rd, 2013	Partly cloudy
3	July 22nd, 2013	Overcast, rainy
4	August 17th, 2013	Cloudy, rainy
5	September 21st, 2013	Sunny, dry

The selected sites include some of the most heavily eroded slopes in the study area, however most slopes and fills in the study area have been protected with geotextile and been subject to re-vegetation or (where

possible) re-forestation, and are experiencing much less erosion than the sites selected for study.

The selected sites therefore represent 'worst case' examples of erosion by land sliding, sheet erosion, rilling and gullying that exist along Route 1856. In this regard, the dimensions of erosion features measured at each site, and annual rates of lowering of the land surface estimated on the basis of those direct observations are much higher than average for Route 1856 as a whole. Consequently, the rates of erosion presented here are highly conservative when applied to the rest of Route 1856.

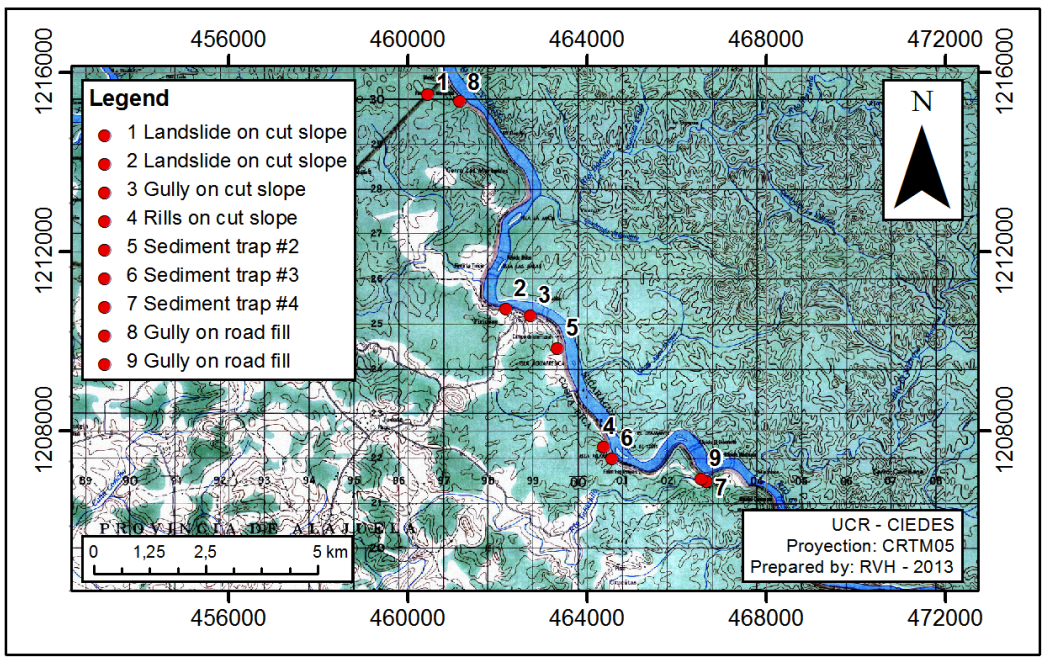


Figure 1. Location of monitored sites.

Sediment yield estimation

The analysis of each of the monitored sites is detailed below; results are given as average annual rate of land surface lowering or average erosion depth, depending on the type of site.

Sheet erosion

Sediment trap #2, shown in Figure 2, was used to provide the estimate for sheet erosion occurring on the road bed and cut slopes. The depth of sediment trapped within the area confined by geo-membrane (Figure 2) was measured at up to sixteen points. These measurements were then combined with the area of the trap to estimate the volume of soil eroded from the trap's tributary area. Finally the eroded volume was divided by the tributary area to determine the average depth of soil lost each day. This was multiplied by the number of days in a year to determine the average annual erosion rate shown in Table 2. The trap is located at the following coordinates: 10°56'26.2"N, 84°20'6.9"W.

Two type of surfaces drain into the sediment trap: a 505.0 square metre bare earth slope and a 332.0 square metre portion of road surface. The area of the trap itself is 58.5 square metres.

Table 2. Field Observations of sediment in Sediment Trap #2.

Date	Average depth (m)	Estimated volume (m3)	Change in volume (m3)	Average Annual rate of land surface lowering (m/yr)
08/06/2013	0.18	10.70	N/A	N/A
23/06/2013	0.22	12.81	2.11	0.061
22/07/2013	0.33	19.11	6.30	0.095
17/08/2013	0.32	18.47	-0.64	-0.011

The estimated annual rate between 22 July and 17 August 2013 is negative because of a one centimetre reduction in average sediment depth. It is unlikely that the volume deposited within the trap decreased during this period, rather the trap was filled to capacity between the dates above. As shown in Figure 2, the trap was nearly full on 22 July. The difference in depth can then be explained as an error margin in the sediment depth measurements in the magnitude of +/- 0.01 m.

As to the difference between the average annual rates on 8 June and 23 July, these can be explained due to an increase in precipitation as the rainy

season began. The 9.5 cm/year estimate represents conditions during the wet months of the year, while the lower erosion rate measured between June and July is representative of conditions during the dry season, because there is less precipitation eroding the road's cuts and fills. It is therefore concluded that using 9.5 cm/year to represent the average annual rate of land surface lowering is conservative because it applies rainy season rate estimates to the whole year.

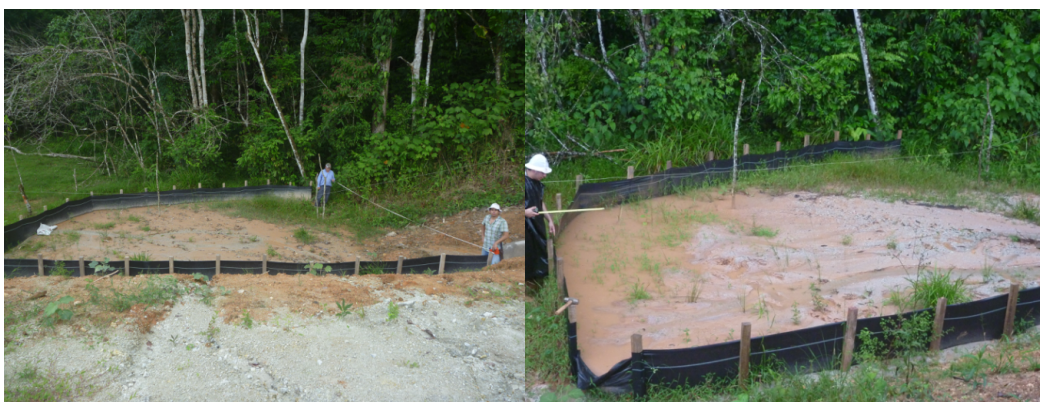


Figure 2. Sediment trap #2 on June 8th (left) and July 22nd (right).

Cut slope erosion

As stated above, the area which drains to the sediment trap only showed evidence of sheet erosion. Three cut slopes, two with a landslide and one with a gully, were surveyed in order to establish their average erosion depth. Site 1 has a landslide with an average depth of 2.96 m which affects an area of 150 m^2; the landslide in Site 2 is smaller, its average depth is 1.01 m and its eroded area is 80 m^2; and finally the gully in Site 3 has an average depth of 0.43 m and a surface area of 14 m^2. Using this information, we obtained an eroded volume for each site, which is then distributed over the entire area of the slope to calculate the average erosion depth for each slope. The results of the measurements made on each feature are shown in Table 3.

The results below are first given as an average depth for the slope and not an annual rate because, unlike the sediment trap, the recorded erosion sites have not shown any appreciable change in size during the five visits to the road between 8 June and 21 September 2013. As the measurements have remained constant over this period of time, an erosion rate cannot be calculated in the same way as was calculated for the sediment trap. Taken together, the average depth of landslide and gully features observed on the

three slopes is 0.17 metres and they occupied 8.6% of total area of the slopes.

In order to estimate an annual rate for these slopes, it is reasonable to assume that these slopes were created when Route 1856 was under construction in 2011, which makes them two years old. This would imply an average annual rate of lowering of the land surface for the slope area as a whole of around 0.085 m/yr (which is 8.5 cm/yr); nevertheless, as discussed below, it is not appropriate to combine landslides and gullies as a uniform geomorphological feature. The average erosion depth for each feature can be found separately in this document's conclusions.

Table 3. Average erosion depth in slopes featuring landslides or gullies.

Site #	GPS coordinates	Type of Feature	Area (m^2)	Erosion type	Eroded area (m^2)	Eroded area/Area of feature (%)	Average erosion depth (m)	Average Annual rate of land surface lowering (m/yr)
1	10° 59' 31.9" N 84° 21' 44.0" W	Road Cut	756	Rotational landslide	80	10.58	0.11	0.06
2	10° 56' 56.2" N 84° 20' 46.1" W	Road Cut	1 168	Rotational landslide	150	12.84	0.38	0.19
3	10° 56' 51.1" N 84° 20' 25.9" W	Road Cut	612	Gully	14	2.29	0.01	0.005

Road fill slope erosion

In addition to the surveyed cut slopes, two road fills with gully erosion were sampled. These two sites had not been included in the original sites because they did not show any erosion features during a preliminary visit during the 2013 dry season. Measurements on these sites were taken during the June and July visits; however final measurements were taken during the September visit. These sites were included to avoid using the same erosion rates for road cuts and fills due to the differing origin of these features. In essence the soil which comprises road cuts has been deposited and compacted over time through natural processes. Road fills are man-made deposits. This difference in origin results in different properties, including their susceptibility to erosion.

Site 8 corresponds to a gully that has been formed due to the flow of water over the road surface and road fill. The softer material of the fill slope had been eroded up to the edge of the road surface by the June visit, however the coarser material of the road seems to be preventing any further

headcutting by the gully and no increase in size was registered up to the July visit. The surface area of this gully is 121 m^2, and its average depth is 1.5 m. In this case it is known that the erosion on this site began after the dry season visit; that is approximately six months prior to the September visit. Therefore the average annual rate of surface lowering may be estimated by doubling the average erosion depth measured over six months, both of these figures are given in Table 4.

Site 9 is a road fill which has been left without a coarse road surface and it features 16 individual gullies of differing sizes. Of these, the largest gully was selected for measurement; it has an area of 7.36 m^2 and a 1 m erosion depth, resulting in an eroded volume of 7.36 m^3. This volume was conservatively multiplied by the number of gullies in the fill to produce an estimated total gully erosion of 118 m^3 for the entire fill feature. The area eroded by the gullies is approximately 118 m^2. When divided by the total area of the fill slope, an Average Erosion Depth of 0.10 m was calculated. Finally, as these measurements were made over the same 6-month time frame used above, the Average Annual Rate of Land Surface Lowering for the fill slope was approximated as double the amount measured over six months, which yields and estimate of 0.20 m/yr.

Table 4. Average erosion depth in fill slopes featuring landslides or gullies.

Site #	GPS coordinates	Type of Feature	Area (m^2)	Erosion type	Eroded area (m^2)	Eroded area/Area of feature (%)	Average erosion depth (m)	Average Annual rate of land surface lowering (m/yr)
8	10° 59' 27.0" N 84° 21' 19.8" W	Road Fill	3 080	Gully	121	3.93	0.06	0.12
9	10° 54' 52.9" N 84° 18' 21.8" W	Road Fill	1183	Gully	118	9.97	0.10	0.20

Rills

A spatial analysis method was used in order to estimate the amount of soil lost due to rill erosion during the monitoring period and therefore to estimate the average erosion depth for slopes which feature rills. Height, depth and width measurements were taken of a metre tall section of a large rill located on the fill slope showing the most intense rill erosion in the studied stretch of road. The measured section had a width of 0.3 m and a depth of 0.6 m which combine with the height and triangular configuration of the rill to indicate a volume of 0.090 m^3 of soil loss for that section. The

location of the studied slope is given by the following coordinates: 10°55'15.9"N, 84°19'33.4"W.

A photograph taken on 17 August 2013 (Figure 3) was then used with the volume calculated above to estimate the volume of soil loss per unit of area of slope. To do this the photograph was scaled using AutoCAD software using a visible measuring tape as reference. The complete photograph and the metre scale are shown in Figure 3.

Figure 3. Cut slope with rill erosion and 1 metre of measuring tape for scale.

Once the photograph above had been scaled, a grid was superimposed over the image (Figure 4). Incomplete grid squares were then clipped before finally counting the number of one metre long rill segments present in the photograph. The 0.090 m^3 of soil loss per metre of rill measured for the largest rill was then applied to all the other metre long segments of rill identified in Figure 4. As Figure 4 shows, most rill segments are shallower and narrower than the measured segment (that labelled 1, in Figure 4); therefore applying the measured volume of soil loss to all the other segments is conservative in that it over-estimates the actual amount of soil eroded by the smaller, narrower rills.

Overall, 26 segments of one metre in length were considered; these yielded a total loss of 2.34 m^3 of soil. When this volume is divided by the 20 m^2 area of the fill slope shown in Figure 4, the average land surface lowering for rills on slopes is 0.12 m. As before, if we accept that this slope was created during the construction of the road in 2011, the annual rate of land surface lowering due to rill erosion since then has been 0.06 m/yr.

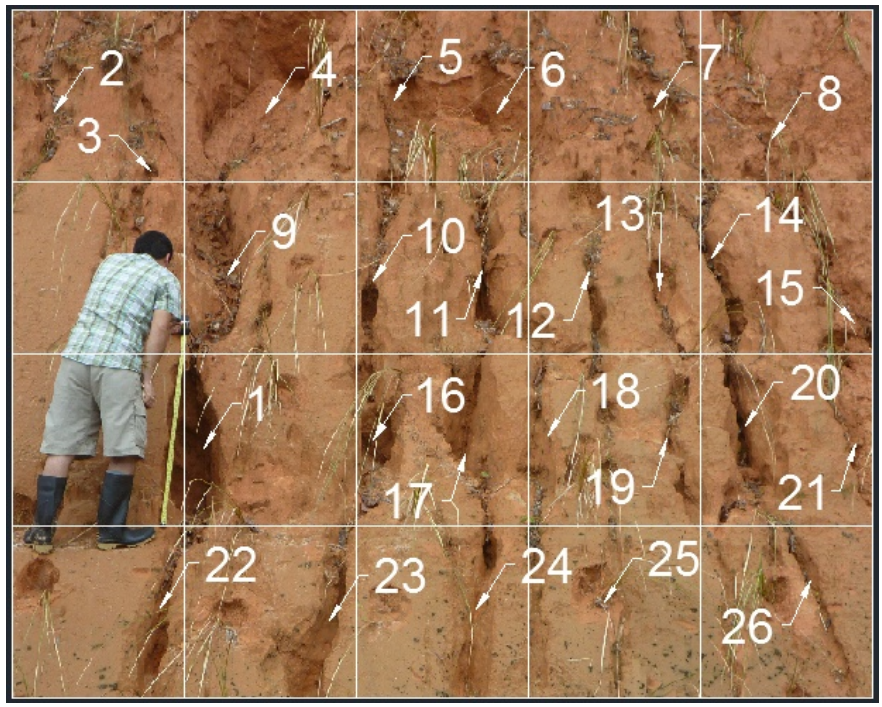


Figure 4. 1 metre rill segments and grid used for Spatial Analysis.

Sediment size distribution and classification

Sediment samples were gathered at four sites: three sediment traps and one cut slope. The cut slope sample was taken from the loose material at the foot of the rotational landslide found Site #2 (see Table 3) and is considered to be representative of the soil of the entire slope. Visual inspection identified a shallow (15-30 cm deep) 'A' horizon and a very deep and uniform 'B' horizon within the soil mass. The sample was taken from this 'B' horizon. The sediment traps are located at the ends of gutters which drain both road surfaces (coarse material) and slopes cut into the terrain

All four samples were processed using the ASTM International (formerly known as the American Society for Testing and Materials) Standard Test Method for Particle-Size Analysis of Soils: D422 – 63 (2007) as well as the Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils: D4318 – 10 (2010). The first Standard Test Method involves the use of sieves and hydrometers to determine the particle size distribution of a soil sample, while the second uses two separate tests for the Plastic Limit and the Liquid Limit. The results of the sediment size distribution and its limits are then used to classify the soil samples according to the Unified Soil Classification System.

Cut slope

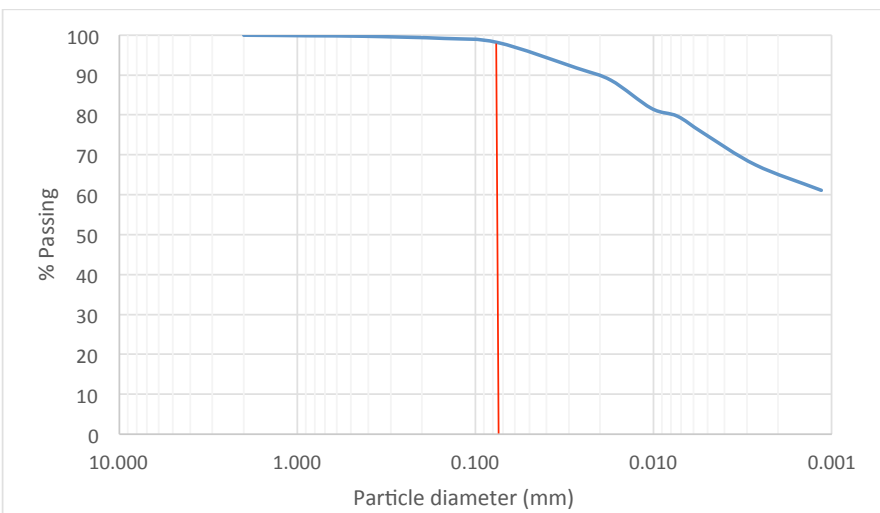


Figure 5. Particle size distribution for the sampled cut slope.
(Note: Red line indicates less than 97% of the sediment is finer than 0.075mm)

As the results in Figure 5 (above) clearly show, the material composing the cut slope is markedly fine (fine sediment being defined as those particles retained by the #200 sieve due to having diameters larger than 0.075 mm), with very little (less than 3%) soil composed of particles with diameters larger than 0.075 mm. This indicates that the behaviour of the soil is likely to be dominated by cohesion between the mainly fine particles that comprise it. The soil's cohesive nature helps explain why most cut slopes have remained stable despite their steep (1:1) gradients.

Sediment trap #2

As shown in Figure 6, this sample contains the greatest amount of coarse material (defined as those particles retained by the #200 sieve or with diameters larger than 0.075 mm) of all the samples. Approximately 23% of the sample passed through the #200 sieve and is therefore classified as fine. During visual inspection of the trap (Figure 7) coarse, grey material eroded from the road bed (which makes up 40% of the area draining to trap #2) was plainly visible among the reddish, fine material derived from the erosion of the cut slopes (which make up 60% of the drainage area). It is believed that the larger amount of coarse material in this sample is due to this trap receiving a greater proportion of runoff and material eroded from the road bed via road gutters compared to the other samples, and is not the result of any difference in the area's soil type compared to the other samples.

(Note: Red line indicates less than 97% of the sediment is finer than 0.075mm)

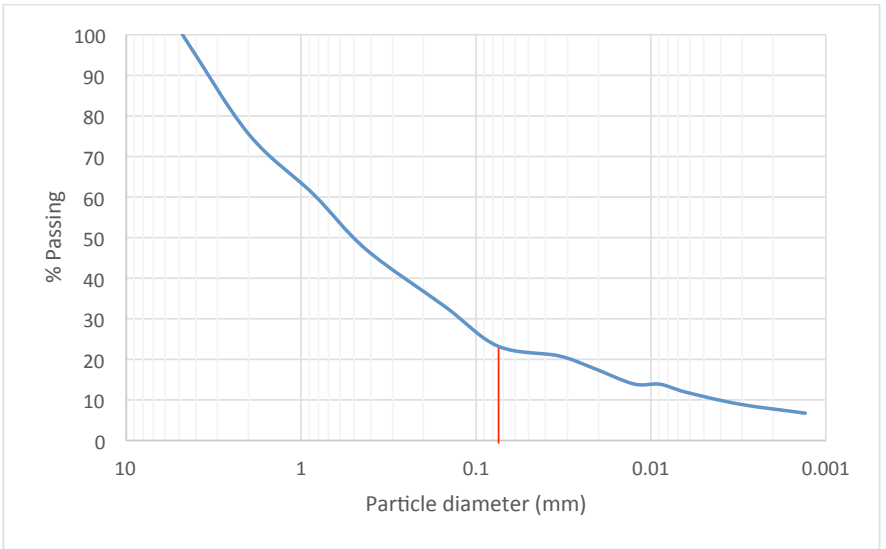


Figure 6. Particle size distribution for sediment trap #2.
(Note: Red line indicates less than 23% of the sediment is finer than 0.075mm)

Figure 7. In-situ photograph of sediment retained by the second sediment trap.

Sediment trap #3

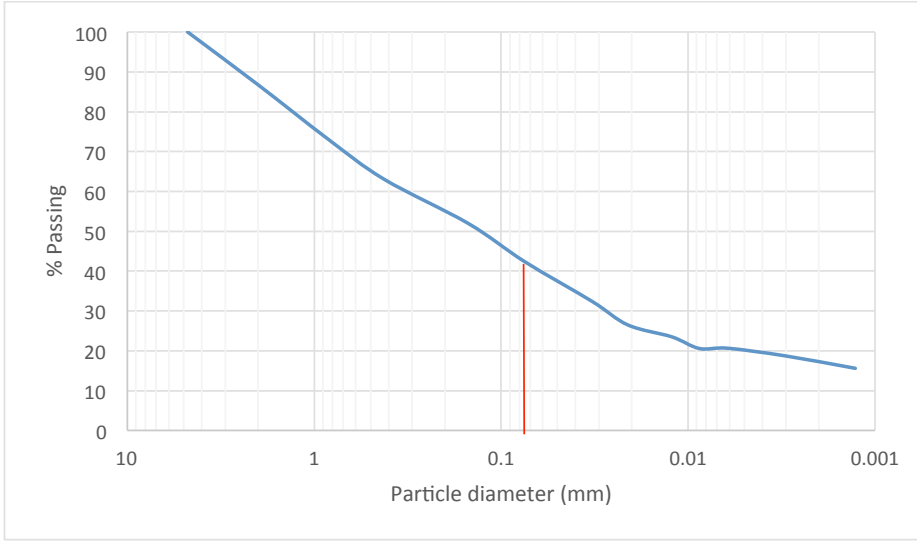


Figure 8. Particle size distribution for sediment trap #3.
(Note: Red line indicates that about 43% of the sediment is finer than 0.075mm)

The sediment sampled in trap #3 has the second highest content of coarse material for all four samples, in that approximately 43% of the soil particles passed through the #200 sieve and are classed as fine. It was not possible to visually examine the sediment found in the trap when it was sampled because the sediment was submerged. The grain size distribution suggests this trap receives coarse material eroded from the road bed as well as fine material eroded from cut slopes that contribute to it; however the percentage of coarse material is smaller than that found in trap #2.

Sediment trap #4

The proportion of coarse sediment in trap #4 is lower than in traps #2 and #3, with fine sediment making up about 75% of the sample. More than half of the soil found in this trap is in fact very fine and Figure 10 shows that the trapped sediment has the reddish-brown colour common to most soils in the studied area. The difference in sediment composition between this and the other two traps may be explained by the presence of an 8.7m wide buffer of bare ground between the concrete gutter and the coarse surface of the road bed, which contrasts with traps #2 and #3, which receive some runoff from gutters connected to the road bed itself.

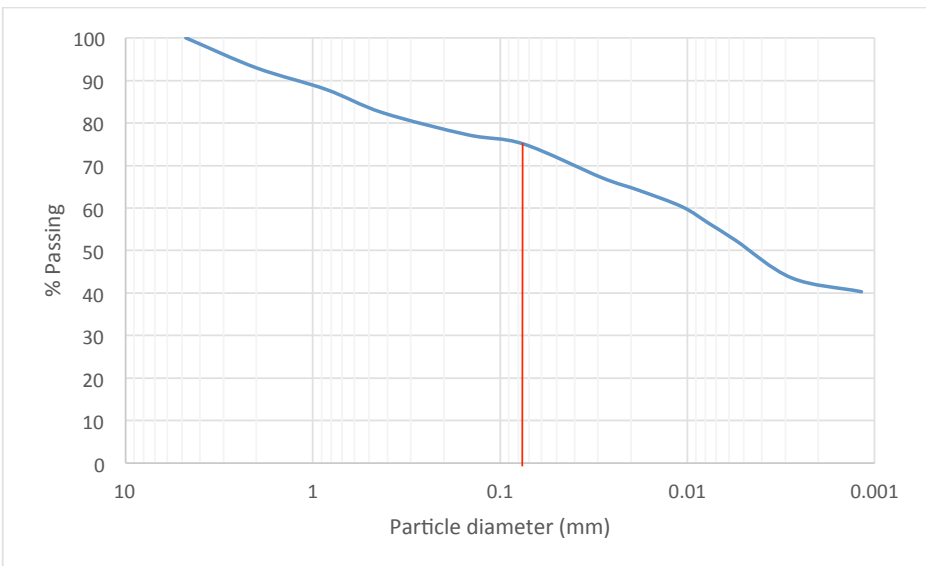


Figure 9. Particle size distribution for sediment trap #4.
(Note: Red line indicates that about 75% of the sediment is finer than 0.075mm)

Figure 10. Sediment collected in trap #4.
(Note reddish-brown colour common to most soils in the studied area)

Summary of Sediment Size and Limit Results

Table 5 lists the overall results for each of the four sampled sites.

Table 5. Result summary and soil classification for each sample.

Sample Attribute	Cut slope	Trap #2	Trap #3	Trap #4	Average
Coarse (%)	1.9	76.7	57.6	24.9	40
Fine (%)	98.1	23.3	42.4	75.1	60
Liquid limit	72	35	30	51	
Plastic limit	40	29	22	39	
Plasticity index	32	6	8	12	
USCS classification	MH-Elastic silt	SM-Silty sand	SC-Clayey sand	ML-Elastic silt with sand	

As mentioned above, the sieve and particle size selected to distinguish between fine and coarse sediment is the #200 sieve which correspond to a particle diameter of 0.075 mm. Plastic and Liquid limits are shown for each soil. The difference between these two limits is then presented as the Plasticity Index. As a final step in the analysis, the size distribution and the

plasticity results were used to classify each sample according to the criteria of the Unified Soil Classification System (USCS).

Contrasts between Landslide and Gully erosion Forms, Triggers and Processes

This section describes and contrasts landslides and gullies as erosive features.

Landslides

The monitored landslides did not show any appreciable change during the monitoring period, because the conditions necessary to trigger landslide activity did not occur during the study period.

Landslides are triggered by one or more of the following:

- deep weathering;
- in the absence of deep weathering, sedimentary or planar structures of variable lithology;
- swelling clays;
- large quantities of soil moisture and positive pore water pressures;
- perennial, seasonal or diurnal ice formations;
- earthquakes; or
- basal undercutting by wave action or rivers.

The landslides observed between Marker II and the Infiernito River occurred only on slopes cut into deeply weathered soil. The moisture conditions present during the occurrence of these landslides are unknown; however, because of the climate in the area it seems likely that high moisture levels and positive pore water pressures triggered these events. No undercutting of slopes has occurred, and there are no indications of swelling clays. Hence, it is unlikely that further landslides will occur unless they are triggered by exceptionally high rainfall (very high moisture contents and positive pore water pressures) or an earthquake. Either could occur, but the frequency of such unusual triggering events is low.

Gullies

The monitored gullies, as well as the landslides, did not show any significant growth during the study period. This can be explained by the fact that the face of the headwall of the gully will be stationary if the

material making up the bed of the knick point has a resistance to shear stress greater than the boundary shear stress provided by the flow, and the flow is insufficient to transport the eroded material from the base of the headwall. This seems to be the case in the monitored gullies. Gullies were observed at some points along the cut and fill slopes of the road, but they were not found to be growing through headcutting at a noticeable rate.

It is important to mention that gully erosion is defined as the "erosion process whereby runoff water accumulates and often recurs in narrow channels and, over short periods, removes soil from these narrow areas to considerable depths" (Poesen et al., 2002). Gullies are often defined for agricultural land in terms of channels that occur in the low areas of the macro topography and that are too deep to ameliorate with ordinary farm tillage equipment, typically ranging in size from 0.5 metres to as much as 25 to 30 metres (Soil Science Society of America, 2001). In the 1980s, the term "ephemeral gully" was introduced to describe concentrated flow erosion larger than a rill but smaller than a classical gully. According to the Soil Science Society of America (2001), ephemeral gullies are "small channels eroded by concentrated overland flow that can easily be filled by normal tillage, only to be reformed in the same location by additional runoff events" (Sedimentation Engineering, American Society of Civil Engineers, 2008).

Contrasts between Landslide and Gully erosion

As discussed in detail above, landslides present in the slopes of Route 1856 are triggered by a specific set of conditions, with soil saturation as one of the most probable causes. Once triggered, landslides occur in a sudden fashion after which there may or not be further landslides in the same site, and the landslides observed in Route 1856 show no evidence of further growth after the initial event

Unlike landslides, gullies are triggered by concentrated overland flow which removes soil in a superficial fashion; the removal of material during the rain events eventually leads to a deepening and widening of the gully. The above implies that gully formation is a gradual process and not a sudden event like a landslide.

Due to the differences inherent to the origination and development between landslides and gullies, it is not meaningful to combine both erosion features when estimating land surface lowering. In addition, no slope in the study area shows both gully and landslide erosion; therefore the locations where

these two separate processes occur are different and have not to date overlapped.

Conclusions

Based on field measurements, rates of soil loss due to sheet erosion of the road bed and cut slopes vary between 0.061 metres and 0.095 metres per year. The difference in the estimates is due to the differences in the amount of soil lost between re-surveys of features made during relatively dry (June - July) and relatively wet (July - August) periods in 2013. Based on these direct measurements it is concluded that the average annual rate of lowering of the land surface due to sheet erosion along Route 1856 lies in the range of ~0.06 to ~0.1 metres per year.

On the monitored cut slopes where landslides were observed, landslides occupied 10 to 13% of the overall area of the slope and had lowered the land surface in those areas by between 0.11 and 0.38 metres. It is reasonable to assume that the slopes were created when Route 1856 was under construction in 2011. Therefore, they have now existed for at least two years. This implies average rates of lowering of the land surface for the entire areas of the slopes due to landsliding of between 0.06 and 0.19 metres per year.

Gullies on cut slopes are the rarest erosion feature in the studied section of Route 1856, while rills are the most common. The gully monitored in the section of road under study had a maximum depth of three metres but covers only just over 2% of the slope it was located in and has a surface area of 13.1 m^2. The total volume of soil eroded to create the gully is approximately 6 m^3. When this volume is divided by the total area of the slope, the average lowering of the surface due to erosion by the gully is 0.01 metres. If it is again assumed that the slope was created when Route 1856 was under construction in 2011, this implies an average rate of lowering of the land surface for the entire area of the slope due to gullying of around 0.005 metres per year.

The majority of slopes along Route 1856 in the study area experience rill erosion. At the rill study site, the largest rill had a maximum width of 0.3 metres and a maximum depth of 0.6 metres, and this represents a ‘worst case’ example of rill erosion in the study area. Based on spatial analysis of all the rills in the sample area, and with the conservative assumption that they all had widths and depths equal to that of the largest rill, it may be

concluded that rill erosion has on average lowered the land surface of the slope by 0.12 metres. Again assuming that the slope was created when Route 1856 was under construction in 2011, this implies an average rate of lowering of the land surface for the entire area of the slope due to rilling of around 0.06 metres per year. This estimate of land surface lowering rate is considered to be conservative for the reasons mentioned above.

Fill slopes in the studied area do not feature landslide erosion. Rill erosion is observed, though it affects smaller areas, with less intensity than in the cut slopes. Therefore use of the depths and annual rates calculated for rill erosion of cut slopes is recommended for fill slopes as well.

Gully erosion on fill slopes is significant, covering approximately 4% to 10% of the measured fills, and resulting in average erosion depths between 0.10 m and 0.06 m. In contrast to erosion of road cuts, this has taken place in a shorter time frame of 6 months. Therefore the estimated average annual rate of land surface lowering for gully erosion of fill slopes is higher, being between 0.12 and 0.20 m/yr.

The results listed in Table 5 show that on average 40% of the sediment reaching the sediment traps is coarse (mainly sand) and that the remaining 60% is fine (silt and clay). It is reasonable to expect that the delivery ratio for coarse sediment (sand) to the San Juan River is much lower than that for silt and clay. Due to its size and mass, coarse material is deposited closer to its point of origin than fine sediment and it is, therefore, much more likely for sand and gravel particles eroded from Route 1856 to remain within Costa Rican territory than it is for them to reach the San Juan River. In addition, as silt and clay move as suspended load through the Rio San Juan, which is a sand-bed river, any silt and clay that were to reach that river is likely to be transferred downstream through the fluvial system to the Delta, where at least 90% of it would return to Costa Rican territory through the Rio Colorado.

In view of the fact that landslide and gully erosion are two different types of geomorphic phenomena, controlled by different geophysical principles, it is not correct to combine or treat landslide and gully erosion as a single geomorphic entity.

Table 6 contains a summary of all the observed average erosion depths and the average annual rates of land surface lowering mentioned in the preceding text. As this summary lists the highest values of eroded area/area

of feature, average eroded depth, and average annual rate of land surface lowering for each erosion type, all estimates conservative.

Table 6. Summary of Results.

Type of feature	Erosion type	Eroded Area/Area of Feature (%)	Average erosion depth (m)	Average rate of land surface lowering (m/yr)
Cut Slope	Landslide	13	0.38	0.19
Cut Slope	Gully	2	0.01	0.005
Cut Slope*	Rill	50	0.12	0.06
Road bed and Cut Slopes	Sheet	N/A	0.02	0.095
Fill Slope	Gully	9	0.10	0.20

*may also be conservatively applied to Fill Slopes.

While the assumption that erosion in the studied features has occurred during the last two years is valid, and therefore the average rates of surface lowering calculated for Landslides, Gullies and Rills on cut slopes are also valid, the use of average erosion depth for these features is recommended as these values are the most conservative for use in further calculations of the impact of Route 1856's sediment production on Nicaragua's San Juan River. Due to the different procedure used to monitor sheet erosion, the use of an average rate of surface lowering of 0.095 m/yr for sheet erosion is recommended. Finally the average rate of surface lowering of 0.20 m/yr is the most conservative value which can be used to estimate gully erosion on road fills and its use is recommended for any further studies.

Bibliography

ASCE Manuals and Reports on Engineering Practice N° 110 2007. *Sedimentation Engineering, Processes, Measurements, Modeling and Practice*. Edited by Marcelo H. García, ASCE, New York, USA.

ASTM International 2007. *ASTM D422 - 63(2007) Standard Test Method for Particle-Size Analysis of Soils*. ASTM International, West Conshohocken, PA, USA.

ASTM International 2010. *D4318 - 10 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*. ASTM International, West Conshohocken, PA, USA.

Dunne T. and Leopold, L.B. 1978. *Water in Environmental Planning*. W.H. Freeman and Company, New York, USA.

Knighton, D. 1998. *Fluvial Forms and Processes: A New Perspective*. Hodder Arnold, UK.

Leopold L.B., Wolman M.G. and Miller J.P. 1995. *Fluvial Processes in Geomorphology*. Reprinted by Dover Publications, Inc. New York, USA.

Ministerio de Medio Ambiente 1998. *Restauración Hidrológico Forestal de Cuencas Hidrográficas*. Editado por Filiberto López Cadenas de Llano.

Poesen, J. et al. 2002. Gully Erosion in Dry Land Environments. Dry land Rivers, in, *Hydrology and Geomorphology of Semi-arid Channels*. Edited by Bull, L. J. and Kirkby, M. J., Wiley, New York,

Soil Science Society of America 2001. *Glossary of Science Terms*. Soil Science Society of America. Madison, Wisconsin,USA.

Annex I – Sediment trap #2 configuration

Sediment reaches trap #2 through a concrete trench nearly 90 m in length. Three distinct types of terrain tribute runoff and sediment to this trench; the first consists of a 332 m^2 section of road surface formed by half the width of the road along 83 m of gutter. The second surface consists of two bare slopes; these are separated for 44.3 m by a terrace which forms the third surface. This terrace is seen edge-on in Figure 11 as the line which divides the slope approximately 1.5 m above the edge of the concrete gutter. Figure 12 shows each area and its dimensions (in metres) separately.

Figure 11. Portion of the area draining to sediment trap #2.

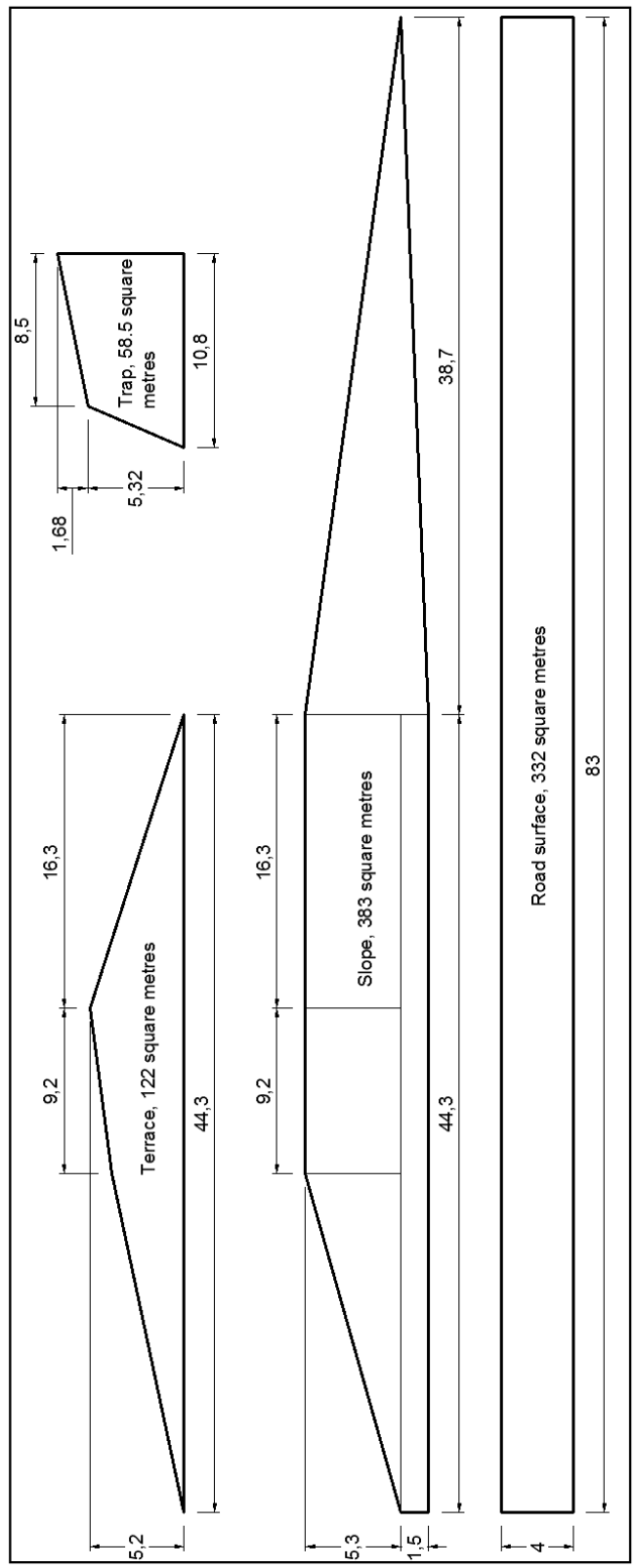


Figure 12. Diagram of sediment trap #2 and its drained slope and road areas.
(Note: the diagram corresponding to the slope is a profile view, all other diagrams are plan view)

ANNEX 2

Comisión de Desarrollo Forestal de San Carlos (CODEFORSA)

Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road

Report of Activities to the Ministry of Foreign Affairs of the Republic of Costa Rica

January 2013

English Translation

COMISIÓN DE DESARROLLO FORESTAL DE SAN CARLOS

Corporate ID number: 3-002-066610-06

Telephone: 2460-1055 Fax: 2460-1650
Email: codeforsa@codeforsa.org
Webpage: www.codeforsa.org
P.O. Box 205-4400 Ciudad Quesada, San Carlos

Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road
SINAC-CDE-004-2012

Report of Activities to the Ministry of Foreign Affairs of the Republic of Costa Rica

January 2013

I. Table of Contents

Page

I. TABLE OF CONTENTS…….. 1
II. INDEX OF APPENDIXES…….. 2

1. INTRODUCTION…….. 3
2. PROJECT PHASES…….. 4

2.1 PHASE 1: PLANNING AND COORDINATION…….. 4

a. Coordination with the Conservation Areas involved…….. 4
b. Coordination with landowners…….. 6
c. Coordination with volunteer groups…….. 10
d. Transportation and support of volunteer groups…….. 13

2.2 PHASE 2: IMPLEMENTATION OF THE WORK PLAN…… 18

a. Scheduling of planting events…….. 18
b. Availability of trees for planting…… 19
c. Preparing the ground and protecting the trees…….. 19
d. Planting of the trees…….. 22

2.3 PHASE 3: MAINTENANCE OF PLANTED AREAS…….. 28

a. Monitoring of planted areas…….. 28
b. Mowing…….. 28
c. Clearing of spots around trees…….. 29
d. Replanting…….. 31
e. Fertilizing…….. 31
f. De-suckering…….. 31
g. Maintenance of fences…….. 31
h. Follow-up visits to planted areas…… 32
i. Quarterly follow-up reports…… 32

2.4 SLOPES…… 33
1. Recovery of slopes …….. 33
2. Maintenance of slopes…….. 35

3. APPENDIXES…….. 37

II. INDEX OF APPENDIXES

APPENDIX 1: Material prepared for participants of the activities and members of public institutions involved

APPENDIX 2: Maps of the areas planted

APPENDIX 3: Visit to the slopes before and after planting

Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road

Direct Contract by Emergency Exception SINAC-CDE-004-2012

Start date: APRIL 2012
End date: APRIL 2014
Proposed project term: 2 years

1. INTRODUCTION

By means of Tender Award Order SINAC-CDE-004-2012 of April 12, 2012, which was declared final on April 19, 2012, the **Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road** tender was officially awarded to COMISIÓN DE DESARROLLO FORESTAL DE SAN CARLOS (CODEFORSA, Commission for Forestry Development in San Carlos).

In conformity with the consulting services agreement signed, a Work Plan was submitted on May 1, 2012 to the office of the Vice-Minister of the Environment for her review and approval. Through official communication DVM-156-2012 the Work Plan for the consulting services was approved; thus, the first phase of the project was completed.

This is a progress report on the activities conducted to implement the Environmental Management Plan for Ruta 1856, the border road.

This document details the progress made in coordinating with the SINAC offices; the signing of participation agreements with the landowners of the areas surrounding San Juan River; and the preparation of the land and planting of the trees by means of 20 events that involved the participation of volunteers from several areas in the country.

One of the commitments included the re-vegetation of 12 slopes located on the built portion of Ruta 1856.

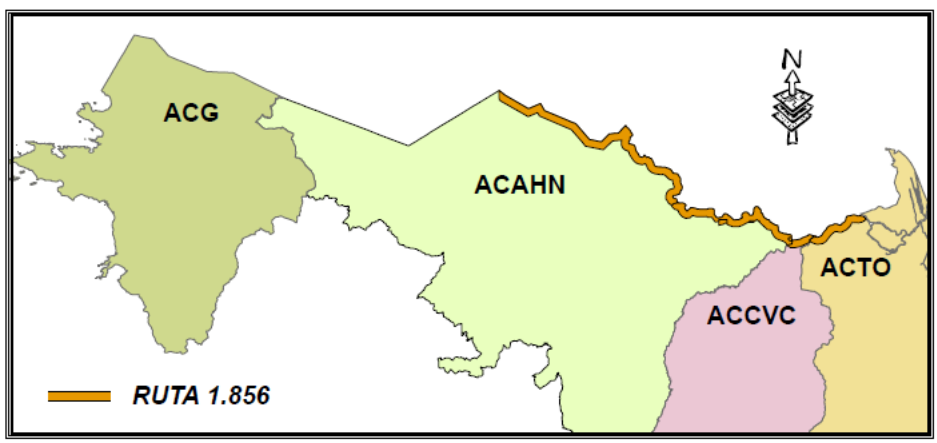
2. PHASES OF THE PROJECT:

2.1 PHASE 1: PLANNING AND COORDINATION OF THE ACTIONS INCLUDED IN THE ENVIRONMENTAL PLAN FOR REVEGETATION

The work plan was developed based on CODEFORSA's field experience in the area where the work was to be performed, and taking into account the terms of reference of the consulting services.

The activities carried out with the different parties involved in the border road sector are presented below.

a. Coordination with Conservation Areas involved:



Map of the built portion of Ruta 1856.

The meetings scheduled with the Conservation Areas of the *Sistema Nacional de Áreas de Conservación* (SINAC) were determined based on the area of influence of each conservation area. As observable in the image above, approximately 80% of the total border road area is in ACAHN territory, followed by ACTO and lastly by ACCVC, which has a 7 km area of influence of the border road in the area currently covered by Ruta 1856, which goes from the Costa Rican Delta to Los Chiles de Alajuela, with an approximate length of 167 km.

To date, eight coordination meetings have been held with the Conservation Areas, as follows: four meetings with the Arenal Huetar Norte Conservation Area (ACAHN); two meetings with the Tortuguero Conservation Area (ACTO); and two meetings with the northern sub-region of the Conservation Area of the Central

Volcanic Range (ACCVC). The project was presented during said meetings, as well as the activities to be carried out as part of the consulting work, with the goal of listening to the opinions of the members of the Conservation Areas.

The problems in the Costa Rican Delta zone were analyzed and discussed with the Tortuguero Conservation Area. Residents are hesitant to participate in the reforestation of the lands they occupy. Their disagreement is mainly related to MINAE's initiative to create a protected wildlife area in Isla Calero. The residents were informed of the details of the project, and the strategy to persuade them was changed to visiting them individually, bringing along a respected person from the area. This allowed earning their trust, and the neighbors signed the agreements necessary to achieve the goal of planting trees for the project in the land held by them and obtaining their collaboration.

The first four tree planting events were conducted in the area of influence of the ACCVC Sarapiquí sub-region, with volunteers accompanied by the officers of this sub-region.

Four meetings were held with the Arenal Huetar Norte Conservation Area (ACAHN). The project was also presented to the Regional Council of the Conservation Area (CORAC HN) and to ACAHN's Forestry Council.

At a meeting with ACAHN's Technical Committee we were provided with a list of possible species to be used for the reforestation of Ruta 1856. They recommended, among other, species for areas susceptible or not susceptible to flooding. All of the species recommended by the Committee agreed with the species currently used at the planting sites.

A total of 5 meetings and 18 monitoring field visits are still pending for the period until April 2014. The goal of the pending meetings is to show the progress of the activities at each sector, namely: Costa Rican Delta, Trinidad (Mouth of Sarapiquí River), Mouth of San Carlos River and Tiricias, as well as monitoring visits to verify the maintenance of the trees planted and slopes treated.

Table Nº1: Schedule of meetings and visits with the different SINAC Areas of Conservation involved

Conservation Area	Coordination meetings																			
	Month																			
	Sept-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Abr-13	May-13	Jun-13	Jul-13	Aug-13	Sept-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Abr-14	TOTAL
Tortuguero (ACTO)						1									1						**2**
Central Volcanic Range (ACCVC)															1						**1**
Arenal Huetar Norte (ACAHN)						1									1						**2**
TOTAL	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**5**

Conservation Area	Field visits with Conservation Areas																			
	Month																			
	Sept-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Abr-13	May-13	Jun-13	Jul-13	Aug-13	Sept-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Abr-14	TOTAL
Tortuguero (ACTO)						1			1			1			1			1		1	**6**
Central Volcanic Range (ACCVC)						1			1			1			1			1		1	**6**
Arenal Huetar Norte (ACAHN)						1			1			1			1			1		1	**6**
TOTAL	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**3**	**0**	**0**	**3**	**0**	**0**	**3**	**0**	**0**	**3**	**0**	**3**	**18**

b. Coordination with landowners or occupants to obtain approval for the establishment of plant cover

Meetings were held with the communities in order to obtain the occupants' approval and establish agreements whereby they facilitate a portion of their land to plant trees and also commit to taking care of them once the project is completed. This included meeting with the inhabitants of: Costa Rican Delta, Trinidad and Fátima; Cureña and the mouth of San Carlos River; and Jocote, Tiricias and Llano Verde in the district of Cutris de San Carlos.

The meetings with the communities were carried out to inform them of the project being executed and its benefits, and of the construction of Ruta 1856, in order to counteract the media's negative attacks on the construction of the border road.

Meeting held at Fátima de Sarapiquí on 5-15-2012

Meeting held at Boca San Carlos on 07-04-2012

Meeting held at Tiricias on 08-16-2012

Two additional meetings are pending for 2013, one in Tambor, Sarapiquí canton, and the other in Las Tablillas, Los Chiles de Alajuela canton.

In addition to the meetings held at the communities, the approaching strategy also consisted of an individual visit to each landholder interested in participating in the project, accompanied by a respected person from the area, which allowed us to gain the residents' trust and thus achieve the signing of the agreements necessary to plant the project's trees in their land and obtain their collaboration.

A total of 23 agreements were signed with occupants along Ruta 1856. It is worth noting that the reforestation agreements located in the area from the Costa Rican Delta to the Mouth of Sarapiquí River are small blocks, with areas ranging from 0.2 ha to 1 ha available to plant the trees. The agreements signed for the reforestation of the areas near the mouth of San Carlos River and Tiricias include areas ranging from 1 to 8 hectares, which allowed us to increase the amount of trees to be planted.

Table Nº 2: List of agreements signed with the landowners for the planting of trees.

No.	Name	Location	Number of trees agreed
1	Félix Hernández Jarquín	Boca Caño La Ceiba	200
2	Adilia Com Hernández (La Ceiba Church)	Boca Caño La Ceiba	150
3	Segundo Gaitán Mora	Boca Río Sarapiquí	450
4	Fabio Vargas Vargas	Boca Caño La Ceiba	300
5	Boca La Ceiba School	Boca Caño La Ceiba	100
6	Melis Góngora Moraga	Boca Caño La Ceiba	300
7	Tito Hernández Ferreto	Delta Costa Rica	250
8	Delta Costa Rica School	Delta Costa Rica	400
9	María Hilaria Miranda Rivas	Boca Caño Las Marías	300
10	Olman Quesada Campos	Tiricias	1.000
11	Daniel Jiménez Berrocal	Tiricias	5.000
12	Gerardo Quirós Picado	Delta Costa Rica	200
13	Olga Retana Miranda	Delta Costa Rica	400
14	Fabio Cedeño G. (Ochoa Farm)	Boca Río San Carlos (Ochoa Farm)	7.000
15	Víctor Ballestero Álvarez	Tiricias	3.000
16	Víctor Ballestero Álvarez Morehead University	Tiricias	3.000
17	Edgar Salazar Ramírez	Tiricias	1.000
18	William Cortés Madrigal	Tiricias	1.000
19	Marcelo Méndez Morales	Tiricias	1.000
20	German Díaz Ruiz	Tiricias	3.000
21	Henry Perera Cunnigham	Cureña	1.000
22	Fritz Perera Jiménez	Cureña	2.000
23	Freddy Ulate Castro	Cureña	5.000
TOTAL TREES ESTIMATED			36.050

c. Coordination with volunteer groups for their participation in the planting events

Twenty planting events have already been completed, with the participation of 766 volunteers from the Central Valley, the Northern area, the Scouts of Cartago, Elementary and High Schools in the Northern area, as well as members of public institutions such as FONAFIFO and SINAC, among others.

To coordinate each planting event with the volunteers it was necessary to carry out significant administrative work, for instance, creating a database of the calls transferred by MINAET to CODEFORSA, of the radio and television campaign encouraging the reforestation of Ruta 1856.

The information of the volunteers who called expressing their interest in planting was taken down, including their names, phone numbers, email addresses and place of residence, as well as on which day they were interested in participating, according to the schedule.

Each volunteer who participated in the planting events was given a shirt, as shown in the photos, along with a cap which had the MINAET and SINAC logos, a pen, a waterproof poncho for the rain, a magazine with project information, highlighting the highway and its characteristics, the reason behind the road's name, and the environmental commitment that is being mitigated by the planting of trees throughout Ruta 1856.

Front of shirt

Back of shirt

Magazine cover

Shirts and hats handed out at each activity

Pens handed out to the participants

Each participant was given breakfast, consisting of gallo pinto, eggs, sour cream, tortillas or bread, coffee or juice. For lunch they were given a casado (typical dish) including meat with sauce, chicken or fish, a natural beverage and desserts, and finally a coffee with a sandwich for their return trip.

Breakfast at Toños Restaurant, October 23, 2012 event, C.T.P high school. Aguas Zarcas

Lunch at San Juan Restaurant, June 23, 2012 event. Volunteers Northern Area

The planting of trees, as mentioned before, was conducted with the assistance of volunteers and CODEFORSA staff. Table No. 3 includes the planting date, the names and places of origin of the assistants, and the number of participants in the planting event.

Table Nº 3 Participation of volunteers in the 20 different planting events

TREE PLANTING EVENTS				
Number	**Date**	**Planting Location**	**Assistants**	**Number of participants**
1	05/06/2012	La Ceiba	Central valley volunteers, MINAET employees Sarapiquí	24
2	12/06/2012	Boca del Río Sarapiquí	Central valley volunteers	21
3	16/06/2012	La Ceiba	FONAFIFO employees, Guías y Scouts Cartago.	40
4	19/06/2012	La Ceiba, Escuela La Ceiba	Central valley volunteers, students from Liceo rural Las Marías and Boca La Ceiba school	41
5	23/06/2012	Boca del Río San Carlos	Northern area volunteers	44
6	28/06/2012	Boca del Río San Carlos	Northern area volunteers, Colegio Saíno, ACAHN employees	30
7	30/06/2012	Delta Costa Rica	Central SINAC employees	45
8	22/08/2012	Tiricias	Colegio El Concho	41
9	23/08/2012	Boca del Río San Carlos	Colegio Saíno, Northern area volunteers	41
10	29/08/2012	Tiricias	Colegio La Guaria	39
11	04/09/2012	Tiricias	Escuela San Isidro	38
12	06/09/2012	Boca del Río San Carlos	Colegios Boca Tapada, Boca San Carlos	38

13	11/09/2012	Tiricias	Escuela Llano Verde and Las Tiricias	46
14	29/09/2012	Boca del Río San Carlos	Fuerza Juvenil Youth Group from Ciudad Quesada	41
15	02/10/2012	Tiricias	Escuela El Concho, Escuela Banderas	41
16	04/10/2012	Tiricias	Colegio Banderas de Pocosol	41
17	11/10/2012	Boca del Río San Carlos	Colegio Gastón Peralta de Altamira	39
18	16/10/2012	Boca del Río San Carlos	Colegio Técnico de Pital	42
19	23/10/2012	Boca del Río San Carlos	Colegio Técnico de Aguas Zarcas	45
20	01/12/2012	Delta Costa Rica	CODEFORSA employees and special guests	29
	TOTAL			**766**

According to the table above, 766 volunteers participated in the 20 planting events, for an average of 38 persons per event. This number is higher the average estimated in the work plan, which was 35 volunteers per activity.

It is also worth noting that the events were carried out along Ruta 1856, as the work was performed at: Costa Rican Delta, La Ceiba, Mouth of Sarapiquí River, Mouth of San Carlos River and Tiricias.

Appendix 1 includes the material prepared to communicate the goals of the consulting services and of the construction of Ruta 1856, as well as the progress in the tree planting activities and a map with the location of the planted sites.

d. Transportation and support of volunteer groups

In all cases, the units used to transport volunteers comply with the MOPT's (Ministry of Transport) technical vehicle inspection requirements, and all vehicle permits were current. During the planting activity, water is provided to the participants, in addition to sun block, mosquito repellent and a waterproof poncho for protection against the rain.

June 5 event

June 16 event

October 16 event

After each planting event a report is prepared describing the day's activity, a list of participants, the place where they came from or institution they represented, and phone number and signature of each person as evidence of the activity performed.

In order to assess the results of the activity, once it is completed the volunteers fill out an evaluation form and provide recommendations.

The form consists of six brief response questions, a space for comments and lastly a space for general recommendations to improve the events. All of these assessments are presented in an appendix to the progress report.

2.2 PHASE 2: IMPLEMENTATION OF THE WORK PLAN

a. Scheduling of the planting events

Once the participation agreements were signed by the inhabitants of the different areas, the activities were scheduled based on the list of agreements.

As indicated in table 4, the last planting event was held on December 1st. Thus, the programming and execution of these events has been completed.

Some sites and dates were changed due to force majeure events. For example, the bridge over Río Sucio fell due to the Sámara earthquake. Consequently, the events programmed for Costa Rican Delta and Trinidad had to be changed; they were performed at the mouth of San Carlos River.

Table Nº 4 Schedule of planting events with volunteers

Name of the area	Planting events with volunteer and student groups																			
	Week																			
	01-jun	02-jun	03-jun	04-jun	01-jul	02-jul	03-jul	04-jul	01-ago	02-ago	03-ago	04-ago	01-sep	02-sep	03-sep	04-sep	01-oct	02-oct	03-oct	01-dic	TOTAL
Delta Costa Rica				1											1			1			3
Trinidad	1	1	2											1							5
Boca San Carlos				2							1		1			1			1	1	7
Tiricias											1	1	1	1			1				5
TOTAL	**1**	**1**	**2**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**20**

Performed Not performed

A total of 20 planting events were performed in the three areas where the work with the volunteers had been contemplated.

Planting event 23-06-2012

Planting event 22-08-2012

Planting event 11-10-2012

b. Availability of trees for planting

CODEFORSA has a certified nursery, from which most of the material planted in the project was sourced. According to the planting schedule, the trees were transferred to the planting site on dates close to or on the same day of the event, in order to prevent damages or theft of trees at the site, and to guarantee optimal strength and development conditions of the trees at the time of planting.

c. Preparing the ground and protecting the trees

Once the agreements of participation in the planting of trees were signed with the inhabitants of the different areas, the planning for preparation of the ground at the different sites began.

BEFORE PLANTING	CURRENT STATE
PLOT IGLESIA BOCA CAÑO LA CEIBA	
PLOT FREDDY ULATE CASTRO	
PLOT TITO HERNANDEZ FERRETO	

BEFORE PLANTING	CURRENT STATE
PLOT DANIEL JIMENEZ (ALONSO)	
PLOT DANIEL JIMENEZ (BISMARK)	
PLOT FELIX HERNANDEZ JARQUIN	

BEFORE PLANTING	CURRENT STATE
PLOT FABIO CEDEÑO (SAN ANTONIO)	

Initial mowing and herbicide spots

For all cases, the preparation of the ground began with a general mowing, tracing and staking. Subsequently, herbicide was applied in the spots around each stake, covering a radius of 1 meter, to guarantee that weeds would not compete with the trees to be planted. Lastly, holes were dug at the sites so that when the planting events took place the volunteers could focus on planting the trees.

Fences

In some cases it was not necessary to place wire fences for protection since there were previous ones in place, while in others a fence was placed to separate the planting area from the rest of the site. In all cases maintenance will be given to the fences as protection of the areas planted.

d. Planting of trees

As visible in table 6, to date the tree planting goal of the project has been reached, with **26.675** trees. The activities began on June 5, 2012 in the Trinidad area, specifically the mouth of La Ceiba River, in the plots of Mr. Félix Hernández and Mrs. Adilia Com. This was followed by activities in the Costa Rican Delta, mouth of San Carlos River and Tiricias. The last tree planting activity was held on December 4, 2012 in the Tiricias area.

The trees were planted at 31 sites, most with the collaboration of volunteers, and another portion planted by the employees of CODEFORSA. It is worth noting that, as indicated in the Work Plan, the blocks that were not completed by the volunteers would be finished by employees of our institution. Consequently, there are more reforested sites than events performed with volunteers.

The species used were as follows:

For protection of the banks of rivers and creeks: *Zygia longifolia* (Sotacaballo).

For humid areas: *Vochysia guatemalensis* (Cebo), *Calophyllum brasiliense* (Cedro María), *Tabebuia rosea* (Roble sabana), *Hyeronima alchorneoides* (Pilón), *Anacardium excelsum* (Espavel).

For high areas: *Vochysia ferruginea* (Botarrama), *Dipteryx panamensis* (Almendro), *Tabebuia ochracea* (Corteza amarilla), *Terminalia amazonia* (Roble coral), *Cordia alliodora* (Laurel), *Delonix regia* (Malinche), *Samanea saman* (Cenizaro) y *Schizolobium parahyba* (Gallinazo).

Table Nº 5: Real number of trees planted at the sites with a plantation agreement and species planted per site

No.	Name of the party to the agreement	Place	Number of trees planted	Date of planting (year 2012)	Species planted
1	Félix Hernández Jarquín	Boca La Ceiba (Trinidad)	260	June 05	sotacaballo, roble coral, pilón, cebo, almendro, maría, roble sabana, bota, malinche, gallinazo, laurel
2	Iglesia Boca La Ceiba	Boca La Ceiba (Trinidad)	225	June 05	sotacaballo, roble coral, pilón, cebo, almendro, maría, roble sabana, bota, malinche, gallinazo, laurel
3	Segundo Gaitán Mora	Boca Río Sarapiquí	100	June 12	sotacaballo
4	Fabio Vargas Vargas	Boca La Ceiba (Trinidad)	407	June 16 and 19	cebo, pilón, sotacaballo, almendro, roble sabana, maría
5	Escuela Boca La Ceiba	Boca La Ceiba (Trinidad)	117	June 19	cebo, pilón, sotacaballo, almendro, roble sabana, maría

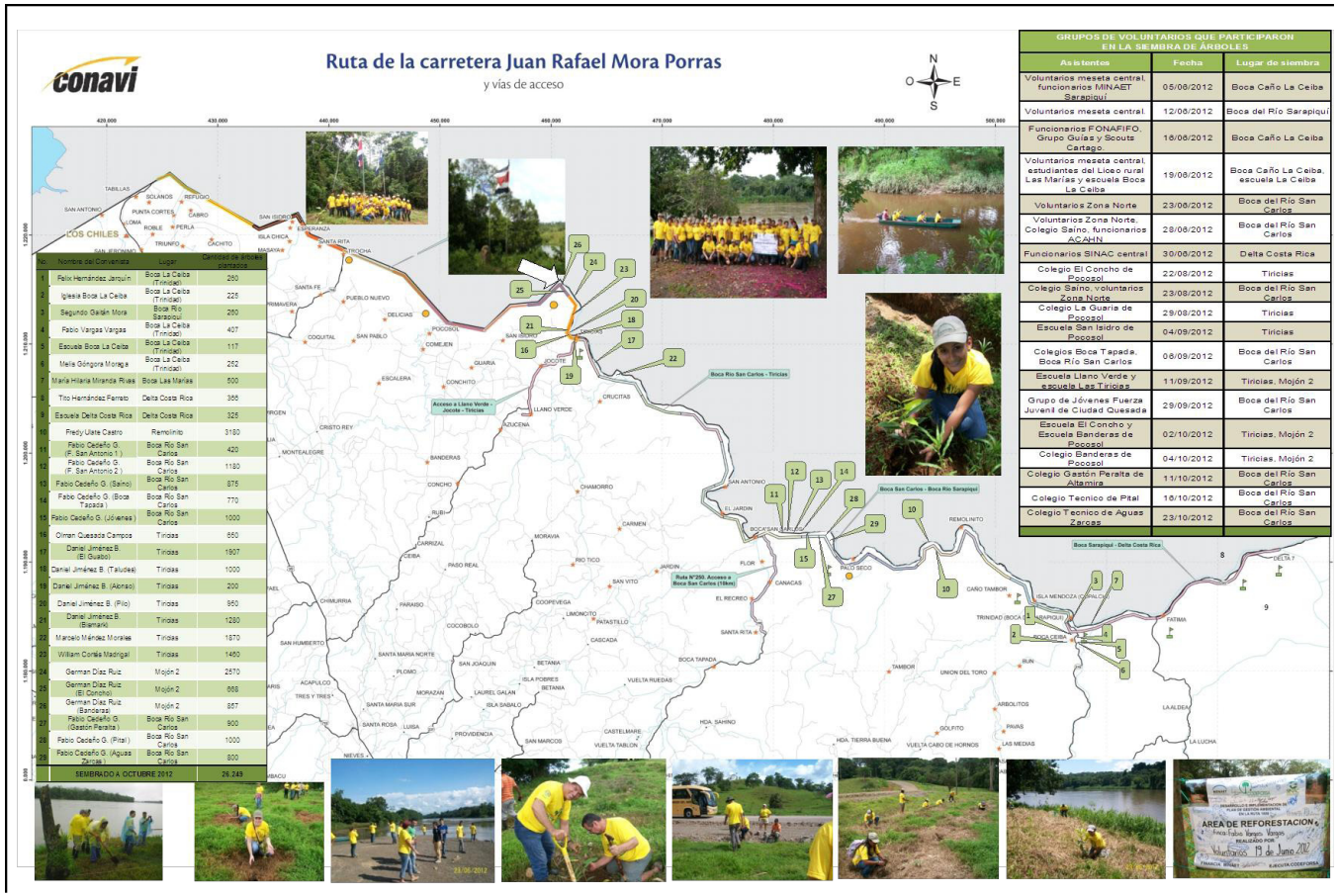
No.	Name of the party to the agreement	Place	Number of trees planted	Date of planting (year 2012)	Species planted
6	Melis Góngora Moraga	Boca La Ceiba (Trinidad)	252	June 19	cebo, pilón, sotacaballo, almendro, roble sabana, maría
7	María Hilaria Miranda Rivas	Boca Las Marías	500	July 15	cebo, sotacaballo, botarrama
8	Tito Hernández Ferreto	Delta Costa Rica	366	June 30	sotacaballo, roble coral, pilón, cebo, roble sabana, maría, cenízaro
9	Escuela Delta Costa Rica	Delta Costa Rica	325	June 30	sotacaballo, roble coral, pilón, cebo, roble sabana, maría, cenízaro
10	Freddy Ulate Castro	Remolinito	3180	September 22	cebo, pilón, sotacaballo, almendro, roble sabana, corteza amarilla, frutales
11	Fabio Cedeño G. (F. San Antonio 1)	Boca Río San Carlos	420	June 23	sotacaballo, roble coral, pilón, cebo, maría, laurel, guapinol, botarrama, roble sabana
12	Fabio Cedeño G. (F. San Antonio 2)	Boca Río San Carlos	1180	June 28	sotacaballo, roble coral, pilón, cebo, almendro, maría, laurel, guapinol
13	Fabio Cedeño G. (Saíno)	Boca Río San Carlos	875	July 04	sotacaballo, roble coral, cebo, almendro, espavel, maría
14	Fabio Cedeño G. (Boca Tapada)	Boca Río San Carlos	770	September 06	sotacaballo, cebo, botarrama, cedro maría
15	Fabio Cedeño G. (Jóvenes)	Boca Río San Carlos	1000	September 29	sotacaballo, botarrama, cebo, guapinol, cenízaro
16	Olman Quesada Campos	Tiricias	650	July 25	roble coral, pilón, maría, laurel, cebo
17	Daniel Jiménez B. (El Guabo)	Tiricias	1907	August 22	sotacaballo, cebo, cedro maría, almendro
18	Daniel Jiménez B. (Slopees)	Tiricias	1000	August 14	sotacaballo
19	Daniel Jiménez B. (Alonso)	Tiricias	200	August 16	sotacaballo, cedro maría, roble sabana, malinche, corteza amarilla, espavel
20	Daniel Jiménez B. (Pilo)	Tiricias	950	August 20	sotacaballo, cebo, cedro maría, pilón
21	Daniel Jiménez B. (Bismark)	Tiricias	1280	August 29	sotacaballo, botarrama, almendro, malinche

No.	Name of the party to the agreement	Place	Number of trees planted	Date of planting (year 2012)	Species planted
22	Marcelo Méndez Morales	Tiricias	1870	August 27	pilón, sotacaballo, cebo, corteza amarilla, almendro, roble coral, botarrama, maría
23	William Cortés Madrigal	Tiricias	1460	August 25	sotacaballo, roble sabana, cebo, espavel, cedro maría, corteza amarilla
24	German Díaz Ruiz	Mojón 2	2570	September 26	sotacaballo, cebo, botarrama, cedro maría
25	German Díaz Ruiz (El Concho)	Mojón 2	668	October 02	sotacaballo, cebo, botarrama, cedro maría
26	German Díaz Ruiz (Banderas)	Mojón 2	857	October 04	sotacaballo, cebo, botarrama, cedro maría
27	Fabio Cedeño G. (Gastón Peralta)	Boca Río San Carlos	900	October 11	Sotacaballo, Roble coral, cebo, botarrama, cedro maría
28	Fabio Cedeño G. (Pital)	Boca Río San Carlos	1000	October 16	sotacaballo, roble coral, guanacaste
29	Fabio Cedeño G. (Aguas Zarcas)	Boca Río San Carlos	800	October 23	sotacaballo, roble coral, guanacaste, cenízaro, botarrama
30	Escuela Delta Costa Rica	Delta Costa Rica	500	December 01	roble coral, botarrama, sotacaballo
31	Edgar Salazar Ramírez	Tiricias	86	December 04	roble coral, pilón, laurel, nogal, aguacate, guanábana, guaba, mango
	TOTAL TREES PLANTED		**26.675**		

The following figure shows a map of the location of all sites already planted along Ruta 1.856. As visible in the map, projects have been established all along this road. The map indicates each point with numbers 1 through 26, given that some lots were joined. The number in the map can be related to the name of each party to the agreement indicated in table 5.

Appendix 2 includes the maps of the lots planted, in which we can see the location of the trees planted in relation to Ruta 1856 and San Juan River.

CODEFORSA's Facebook page includes pictures of the planting events. It is attached to this report in digital format, showing the volunteers who participated in each event, material prepared and external signs provided, as well as the sites where the trees were planted.



No.	Nombre del Convenista	Lugar	Cantidad de árboles plantados
1	Felix Hernández Jaroun	Boca La Ceiba (Trinidad)	260
2	Iglesia Boca La Ceiba	Boca La Ceiba (Trinidad)	225
3	Segundo Gatgán Mora	Boca Río Sarapiquí	250
4	Fabio Vargas Vargas	Boca La Ceiba (Trinidad)	407
5	Escuela Boca La Ceiba	Boca La Ceiba (Trinidad)	117
6	Mela Góngora Moraga	Boca La Ceiba (Trinidad)	252
7	María Hilaria Miranda Rivas	Boca Las Marías	500
8	Tito Hernández Ferrato	Delta Costa Rica	366
9	Escuela Delta Costa Rica	Delta Costa Rica	325
10	Fredy Ulate Castro	Remolinito	3180
11	Fabio Cedeño G. (F. San Antonio 1)	Boca Río San Carlos	420
12	Fabio Cedeño G. (F. San Antonio 2)	Boca Río San Carlos	1180
13	Fabio Cedeño G. (Saino)	Boca Río San Carlos	975
14	Fabio Cedeño G. (Boca Tapada)	Boca Río San Carlos	770
15	Fabio Cedeño G. (Jóvenes)	Boca Río San Carlos	1000
16	Olman Quesada Campos	Tiricias	650
17	Daniel Jiménez B. (El Guabo)	Tiricias	1907
18	Daniel Jiménez B. (Taludes)	Tiricias	1000
19	Daniel Jiménez B. (Alonso)	Tiricias	200
20	Daniel Jiménez B. (Pío)	Tiricias	950
21	Daniel Jiménez B. (Bamank)	Tiricias	1280
22	Marcelo Méndez Morales	Tiricias	1870
23	William Cortés Madrigal	Tiricias	1450
24	German Díaz Ruiz	Mojón 2	2570
25	German Díaz Ruiz (El Concho)	Mojón 2	668
26	German Díaz Ruiz Banderas	Mojón 2	957
27	Fabio Cedeño G. (Gastón Peralta)	Boca Río San Carlos	900
28	Fabio Cedeño G. (Pital)	Boca Río San Carlos	1000
29	Fabio Cedeño G. (Aguas Zarcas)	Boca Río San Carlos	900
	SEMBRADO A OCTUBRE 2012		26.249

GRUPOS DE VOLUNTARIOS QUE PARTICIPARON EN LA SIEMBRA DE ÁRBOLES		
Asistentes	Fecha	Lugar de siembra
Voluntarios meseta central, funcionarios MINAET Sarapiquí	05/06/2012	Boca Caño La Ceiba
Voluntarios meseta central.	12/06/2012	Boca del Río Sarapiquí
Funcionarios FONAFIFO, Grupo Guías y Scouts Cartago.	16/06/2012	Boca Caño La Ceiba
Voluntarios meseta central, estudiantes del Liceo rural Las Marías y escuela Boca La Ceiba	19/06/2012	Boca Caño La Ceiba, escuela La Ceiba
Voluntarios Zona Norte	23/06/2012	Boca del Río San Carlos
Voluntarios Zona Norte, Colegio Saíno, funcionarios ACAHN	28/06/2012	Boca del Río San Carlos
Funcionarios SINAC central	30/06/2012	Delta Costa Rica
Colegio El Concho de Pocosol	22/08/2012	Tiricias
Colegio Saíno, voluntarios Zona Norte.	23/08/2012	Boca del Río San Carlos
Colegio La Guaria de Pocosol	29/08/2012	Tiricias
Escuela San Isidro de Pocosol	04/09/2012	Tiricias
Colegios Boca Tapada, Boca Río San Carlos	06/09/2012	Boca del Río San Carlos
Escuela Llano Verde y escuela Las Tiricias	11/09/2012	Tiricias, Mojón 2
Grupo de Jóvenes Fuerza Juvenil de Ciudad Quesada	29/09/2012	Boca del Río San Carlos
Escuela El Concho y Escuela Banderas de Pocosol	02/10/2012	Tiricias, Mojón 2
Colegio Banderas de Pocosol	04/10/2012	Tiricias, Mojón 2
Colegio Gastón Peralta de Altamira	11/10/2012	Boca del Río San Carlos
Colegio Tecnico de Pital	16/10/2012	Boca del Río San Carlos
Colegio Tecnico de Aguas Zarcas	23/10/2012	Boca del Río San Carlos

2.3 PHASE NO. 3. MAINTENANCE OF THE PLANT COVER

a. Monitoring of planted areas

As of July 2012 follow-up visits are performed to the planted areas, both by the volunteers and by the employees of CODEFORSA.

As part of the initial maintenance stage of all plots planted, once a month had passed a general maintenance program was applied, given that maintenance needs are very similar. The following activities were implemented:

1. *Total mowing of the planted area with a hedge trimmer.*
2. *Manual maintenance, with a shovel, of a circular spot with a 30 cm diameter around the tree, followed by earthing-up of each tree.*
3. *Replanting in the event of dead trees.*
4. *With the earthing-up of each tree, planting defects such as crooked trees, trees planted below the soil level, etc. are corrected.*
5. *For leaning trees, anchor with a stake and tie with a string.*
6. *Apply 60 grams of fertilizer to each tree.*
7. *Check the fence to see if any repairs are required, by sector.*
8. *If leaf-cutter ants are found, apply insecticide.*

In the accompanying photos you can see the progress of the activities performed on the plots planted.

Three teams are working on this task, one in the mouth of San Carlos River, another in La Ceiba - Trinidad de Sarapiquí area, and the third one in the Costa Rican Delta area.

b. Mowing:

The first activity for each plot is a complete mowing with a hedge trimmer. There is a variety of weeds in each lot. The one that causes the main problems is called *gamalote*, or bullgrass, which grows very aggressively and its roots spread through the ground which makes its cleaning difficult.

Mowing of *rotana* grass (*ischaemum indicum*)

Mowing of bullgrass (*gamalote* in Spanish)

As the plots were established, the initial maintenance plan was applied. At this time all plots have undergone the initial maintenance plan. General mowing is being applied to all planted plots as of January.

Table 6 shows the scheduled mowing to be performed during the effective period of the consulting work.

Table Nº 6 Scheduled maintenance mowing for each planted plot

Name of the area	Maintenance mowing																							
	Month																							
	may-12	jun-12	jul-12	ago-12	sep-12	oct-12	nov-12	dic-12	ene-13	feb-13	mar-13	abr-13	may-13	jun-13	jAul-13	ago-13	sep-13	oct-13	nov-13	dic-13	ene-14	feb-14	mar-14	abr-14	TOTAL
Delta Costa Rica			2							2								2							6
Fátima			1							1								1							3
Trinidad			7							7								7							21
Boca San Carlos			9							9								9							27
Tiricias			12							12								12							36
TOTAL	**0**	**0**	**31**	**0**	**0**	**0**	**0**	**0**	**0**	**31**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**31**	**0**	**0**	**0**	**0**	**0**	**0**	**93**

Performed In process Not performed

c. Clearing of circular spots around trees:

Herbicide spots

Manual clearing of spots and earthing-up

Part of the maintenance program consists of manually clearing circular spots with a shovel, 40 cm wide, around each tree. As visible in the picture, this works guarantees that there is no competition between the planted trees and weeds. Due to the aggressiveness of bullgrass (*gamalote* in Spanish, scientific name: *paspalum fasciculatum wild*), in the plots were this type of grassy weed existed an herbicide spot was applied, specifically glyphosate, which is a green-label herbicide permitted by international certifiers such as FSC or ISO 14001.

Along with the manual and chemical spot, earthing-up was performed around each tree. As shown in the picture, this consists of putting an amount of soil around the tree so it has fertile and non-compacted soil available for the development of roots. Earthing-up also helps correct planting defects such as trees planted below the soil's level, exposed roots, inclined trees or lack of compacting at the time of planting, which may cause fungus in the roots and death of the tree.

Table Nº 7 Scheduled maintenance of circular spots for each planted unit

Name of the area	***Maintenance of circular spots around trees***																					
	Month																					
	jul-12	*ago-12*	*sep-12*	*oct-12*	*nov-12*	*dic-12*	*ene-13*	*feb-13*	*mar-13*	*abr-13*	*may-13*	*jun-13*	*jul-13*	*ago-13*	*sep-13*	*oct-13*	*nov-13*	*dic-13*	*ene-14*	*feb-14*	*mar-14*	***TOTAL***
Delta Costa Rica	*2*					*2*			*2*				*2*				*2*					***8***
Fátima		*1*				*1*			*1*				*1*				*1*					***4***
Trinidad		*7*				*7*			*7*				*7*				*7*					***28***

Name of the area	*Maintenance of circular spots around trees*																				
	Month																				
	jul-12	*ago-12*	*sep-12*	*oct-12*	*nov-12*	*dic-12*	*ene-13*	*feb-13*	*mar-13*	*abr-13*	*may-13*	*jun-13*	*jul-13*	*ago-13*	*sep-13*	*oct-13*	*nov-13*	*dic-13*	*ene-14*	*feb-14*	*mar-14*	*TOTAL*
Boca San Carlos	*8*	*1*				*9*			*9*				*9*				*9*					*36*
Tiricias	*10*	*2*				*12*			*12*				*12*				*12*					*48*
TOTAL	***20***	***11***	***0***	***0***	***0***	***31***	***0***	***0***	***31***		***0***	***0***	***31***	***0***	***0***	***0***	***31***	***0***	***0***	***0***	***0***	***124***

Performed In process Not performed

d. Replanting:

When the maintenance program was applied to each plot, the trees that had been lost at that time were replanted.

In the monthly visit reports we verify and indicate the number of trees to be replaced, if necessary, to maintain the initial number of trees planted at that plot. This activity is constantly performed at the plots until the end of the project.

e. Fertilizer application:

This work was performed after the earthing-up of the trees, as part of the initial maintenance plan. A dose of 60 grams of 10-30-10 fertilizer was applied to each tree.

Table Nº 8 Application of soil amendments for each planted unit

Name of the area	**Amendments applied to the sites**															
	Month															
	jul-12	ago-12	sep-12	oct-12	nov-12	dic-12	ene-13	feb-13	mar-13	abr-13	may-13	jun-13	jul-13	ago-13	sep-13	oct-13
Delta Costa Rica	A							B				C				
Fátima		A						B					C			
Trinidad		A						B					C			
Boca San Carlos	A							B				C				
Tiricias		A						B					C			

A: Compound fertilizer, B: Foliar fertilizer, C: Liming. For the 31 planting units.

Performed Not performed

f. De-suckering:

This work will not be performed at this time. It has been programmed as of June of next year.

g. Maintenance of the fences:

According to the approved Work Plan, this activity will be performed until June of this year. However, as part of the maintenance visits program carried out at the planted plots, the fences are checked, to prevent the entrance of cattle to the sites. In some cases they have been reinforced with more fence posts when the land is uneven and this allows small animals to pass through.

h. Follow-up visits to the planted areas

As of July 2012 follow-up visits are performed to the planted areas. As per the work plan, during the first year of the project visits must be performed monthly. The quarterly reports of the visits performed are presented by the unit executing the project, including the reports of the visits performed.

Table Nº 9 Schedule of follow-up visits to each planting unit

Name of the area	Follow-up visits																								
	Mes																								
	may-12	jun-12	jul-12	ago-12	sep-12	oct-12	nov-12	dic-12	ene-13	feb-13	mar-13	abr-13	may-13	jun-13	jul-13	ago-13	sep-13	oct-13	nov-13	dic-13	ene-14	feb-14	mar-14	abr-14	TOTAL
Delta Costa Rica	0	1	1	1	1	1	1	2	2	2	2	2		2		2		2		2		2		2	**28**
Fátima	0	1	1	1	1	1	1	1	1	1	1	1		1		1		1		1		1		1	**17**
Trinidad	0	7	7	7	7	7	7	7	7	7	7	7		7		7		7		7		7		7	**119**
Boca San Carlos	0	2	3	4	6	9	9	9	9	9	9	9		9		9		9		9		9		9	**132**
Tiricias	0	0	1	9	11	11	11	12	12	12	12	12		12		12		12		12		12		12	**175**
TOTAL	**0**	**11**	**13**	**22**	**26**	**29**	**29**	**31**	**31**	**31**	**31**	**31**		**31**		**31**		**31**		**31**		**31**		**31**	**471**

Performed Not performed

The approved work plan had proposed and budgeted 422 follow-up visits in total. However, during its execution 31 planting sites were established, and the number of visits were increased. Currently, 471 visits remain to be performed until the end of the project.

i. Quarterly follow-up reports

Table 10 shows the schedule for presentation of the quarterly progress reports to the unit executing the project, which is the office of Área de Conservación Tortuguero. After the presentation of each report a visit is performed with the technical supervisors of the consulting work, which are employees of the three SINAC conservation areas involved. With the supervision reports of SINAC officers the payments are authorized by the project's financial supervisor.

Table Nº 10. Schedule for presentation of progress reports of the project

Name of the area	Progress reports																							
	Month																							
	may-12	jun-12	jul-12	ago-12	sep-12	oct-12	nov-12	dic-12	ene-13	feb-13	mar-13	abr-13	may-13	jun-13	jul-13	ago-13	sep-13	oct-13	nov-13	dic-13	ene-14	feb-14	mar-14	abr-14	TOTAL
Presentation of reports			1			1			1			1			1			1			1			1	8
TOTAL	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**1**	**8**

Performed Not performed

2.4 SLOPES

a. Recovery of slopes

To carry out the recovery of slopes, as part of the project's commitments, the decision was made, after walkthroughs of the areas of influence of the project, that the Tiricias area has the most pronounced terrain cuts. Thus, the approved recovery of 12 slopes shall be performed there.

Design of grass planting on each slope

To date, a total of 8 slopes have been planted and signs were put in place. The work performed is for maintenance.

View of Slope No. 2

Signs placed at each of the slopes

Regarding the progress of the slope recovery schedule, this activity was delayed a little, taking advantage of the winter, to complete the tree planting events. Thus, the four slopes pending work has not begun.

The work on these slopes will be performed as of March of this year, when the teams that are working on the construction of Ruta 1856 allow access to the east of the mouth of Infiernillo River, given that in this area between the mouth of Infiernillo and Chorreras there are areas with significant slopes.

Table Nº 11 Work schedule for recovery of slopes

Work area	**Recovery of slopes**						
	Week						
	03-sep	04-sep	01-oct	02-oct	03-oct	04-oct	**TOTAL**
Slope 1	1						**1**
Slope 2	1						**1**
Slope 3		1					**1**
Slope 4		1					**1**
Slope 5			1				**1**
Slope 6			1				**1**
Slope 7				1			**1**
Slope 8				1			**1**
Slope 9					1		**1**
Slope 10					1		**1**
Slope 11						1	**1**
Slope 12						1	**1**
TOTAL	**2**	**2**	**2**	**2**	**2**	**2**	**12**

Performed Not performed

b. Maintenance of plant cover on slopes:

To date the maintenance work of the plant cover on slopes has consisted of applying foliar fertilizer to promote its establishment and to guarantee that the slopes are covered with vegetation.

Foliar fertilizer is used, with the formula 10-50-10, to favor vertical growth. It is applied with a back pump, using a rod and long hose to completely cover each step of the slopes that were treated. Two applications have been made, one in December, which was not programmed, but it was performed to strengthen the plant cover before the dry season began. A new application is programmed for May, when the rainy season begins.

Foliar fertilization low part of the slope

Foliar fertilization top part of the slope

Table Nº 12 Schedule for maintenance of plant cover on slopes

Name of the area	Maintenance of slopes																							
	Month																							
	jun-12	jul-12	ago-12	sep-12	oct-12	nov-12	dic-12	ene-13	feb-13	mar-13	abr-13	may-13	jun-13	jul-13	ago-13	sep-13	oct-13	nov-13	dic-13	ene-14	feb-14	mar-14	abr-14	TOTAL
Slope 1				1			1					1								1				3
Slope 2				1			1					1								1				3
Slope 3				1			1					1								1				3
Slope 4				1			1					1								1				3
Slope 5				1			1					1								1				3
Slope 6				1			1					1								1				3
Slope 7				1			1					1								1				3
Slope 8				1			1					1								1				3
Slope 9				1								1								1				3
Slope 10				1								1								1				3
Slope 11				1								1								1				3
Slope 12				1								1								1				3
TOTAL	**0**	**0**	**0**	**12**	**0**	**0**	**8**	**0**	**0**	**0**	**0**	**12**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**0**	**0**	**0**	**36**

(A) Foliar fertilization applied Not executed

III. APPENDIXES

APPENDIX 1: MATERIAL PREPARED FOR PARTICIPANTS OF THE ACTIVITIES AND MEMBERS OF PUBLIC INSTITUTIONS INVOLVED

8-PAGE MAGAZINE GIVEN TO EACH VOLUNTEER AT THE PLANTING EVENTS

El plan de trabajo consiste en la ejecución de actividades para mitigar los impactos producidos por la construcción de la carretera en dos áreas específicas que son:

SIEMBRA DE ÁRBOLES.

El proyecto contempla la siembra de 25.000 árboles de especies nativas en los sectores a orilla del río San Juan y en áreas aledañas a la ruta 1856.

A Octubre de 2012 se han plantado 26.249 árboles en tres sectores de la Ruta 1.856, a saber: Delta Costa Rica y Trinidad (2.712 árboles); Boca del Río San Carlos, Cureña y Remolinito (10.125 árboles) y Boca Río Infiernillo, Tiricias, Mojón 2 (13.412 árboles). Se han realizado un total de 19 eventos de siembra con la participación de 733 voluntarios de varias zonas del país, los cuales descubrieron las bellezas de esta poco conocida zona de Costa Rica.

Las especies de árboles utilizadas son:

Como amarre del terreno en bordes del ríos y quebradas: *Zygia longifolia* (Sotacaballo).

Para zonas húmedas: *Vochysia guatemalensis* (Cebo), *Calophyllum brasiliense* (Cedro María), *Tabebuia rosea* (Roble sabana), *Hyeronima alchorneoides* (Pilón), *Anacardium excelsum* (Espavel).

Para zonas altas: *Vochysia ferruginea* (Botarrama), *Dipteryx panamensis* (Almendro), *Tabebuia ochracea* (Corteza amarilla), *Terminalia amazonia* (Roble coral), *Cordia alliodora* (Laurel), *Delonix regia* (Malinche), *Samanea saman* (Cenizaro) y *Schizolobium parahyba* (Gallinazo).

RECUPERAR COBERTURA EN TALUDES.

En cuanto a la recuperación de la cobertura vegetal en los taludes de la ruta 1.856, se ha trabajado en la siembra de material vegetal, el cual se ha sometido a un proceso de fertilización constante para asegurar su establecimiento y que rápidamente cubra los sitios tratados para evitar la erosión y arrastre se sedimentos principalmente en lo más fuerte de la época lluviosa en los mese de octubre a diciembre.

De 12 taludes planeados ya se han completado los trabajos en 8 de ellos con la siembra y fertilización foliar de la cobertura establecida.

Todas estas actividades se ha realizado por medio de una estrecha coordinación con las autoridades del las Áreas de Conservación involucradas, las comunidades aledañas a la Ruta 1.856 y la sociedad civil.

SINAC
SISTEMA NACIONAL DE ÁREAS DE CONSERVACIÓN

CODEFORSA
Desarrollo Forestal Sostenible

MINAET
MINISTERIO DEL AMBIENTE ENERGÍA Y TELECOMUNICACIONES

REFORESTANDO LA RUTA 1856

La construcción de la Ruta 1.856 parte de una necesidad del Gobierno Costarricense, de proteger la soberanía y resguardar la seguridad de los habitantes de toda la frontera con Nicaragua, que han tenido por siempre como vía de comunicación el Río San Juan.

Dicha construcción inicia a mediados del año 2.011 con un camino de lastre que inicia en la localidad de Delta Costa Rica en el cantón de Sarapiquí y se extiende por 160 kilómetros hasta la comunidad de Las Tablillas en Los Chiles, Frontera Norte.

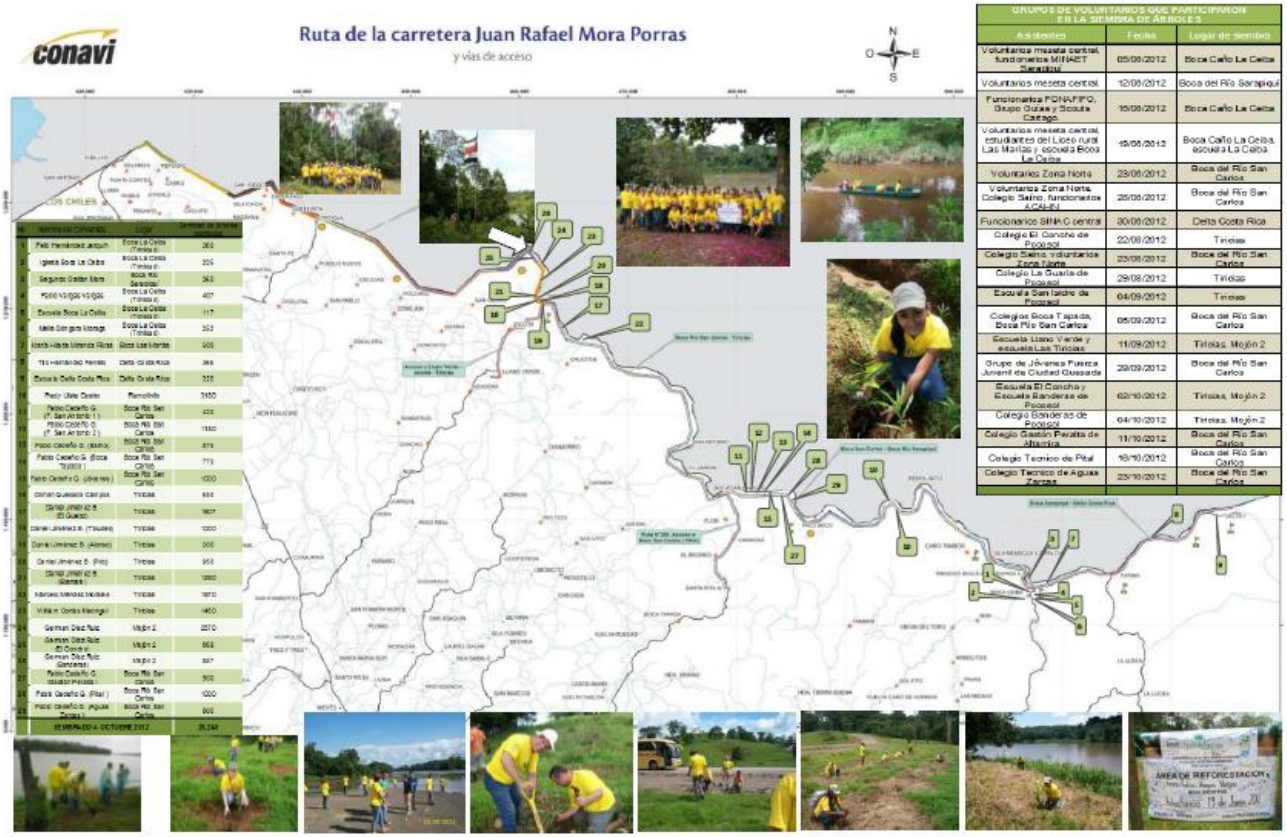
Esta carretera se desarrolla en una zona de difícil acceso con topografías y suelos variados y zonas sin acceso terrestre en donde también se tuvo que habilitar rutas de acceso a la margen del Río San Juan.

Los pobladores de estas zonas que antes tenían sus casas construidas con frente al Río San Juan, ahora cambiaron las fachadas con frente a la nueva carretera.

Junto con el acceso a sus viviendas por vía terrestre, los pobladores de estas zonas han tenido acceso también a la corriente eléctrica y la facilidad de introducir equipos para facilitar las labores de campo como máquinas de ordeño, enfriadores, maquinaria para preparación del terreno, etc.

COMPROMISO AMBIENTAL EN LA RUTA 1856

El Sistema Nacional de Áreas de Conservación (SINAC) como encargado de velar por la protección y vigilancia de los recursos aledaños al Río San Juan, por localizarse dentro del Corredor Biológico Froenterizo, sacó a concurso la consultoría denominada *"Consultoría para el desarrollo de un plan de gestión ambiental en el camino Fronterizo Juan Rafael Mora Porras"* la cual fue otorgada a la Comisión de Desarrollo Forestal de San Carlos (CODEFORSA) para que se encargue de ejecutar el Plan de Gestión Ambiental para la Ruta 1856.

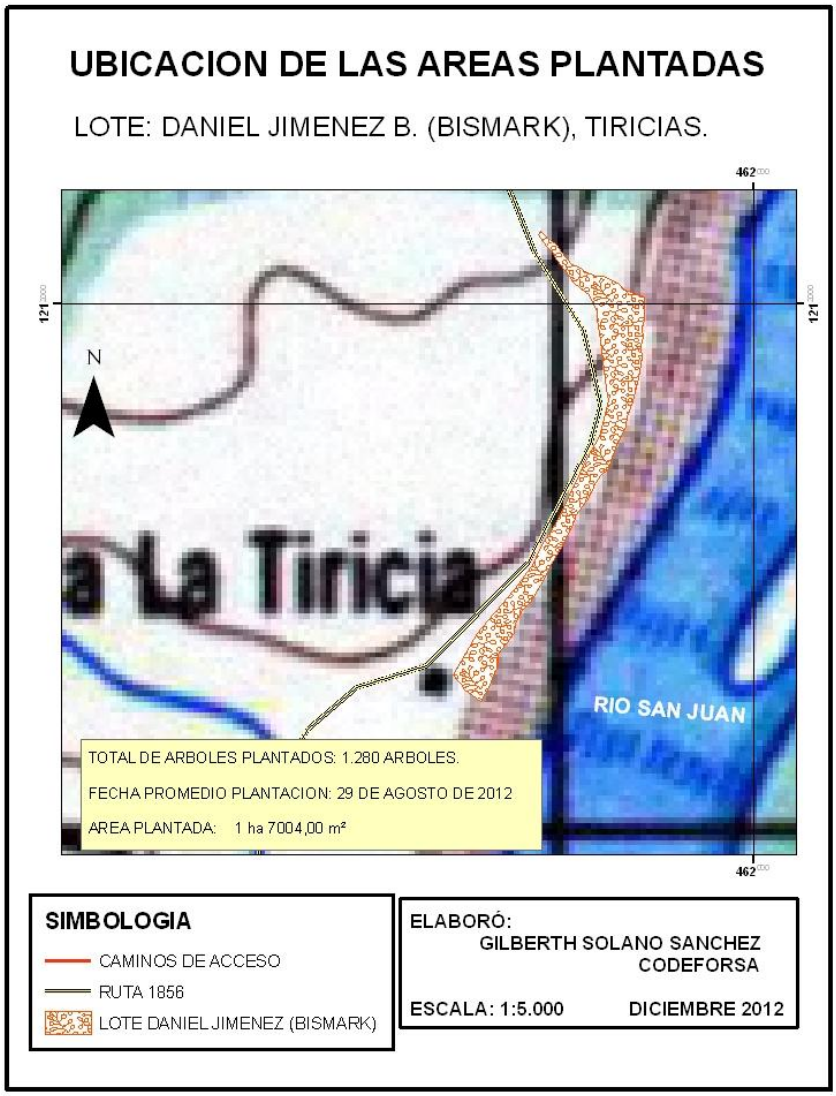


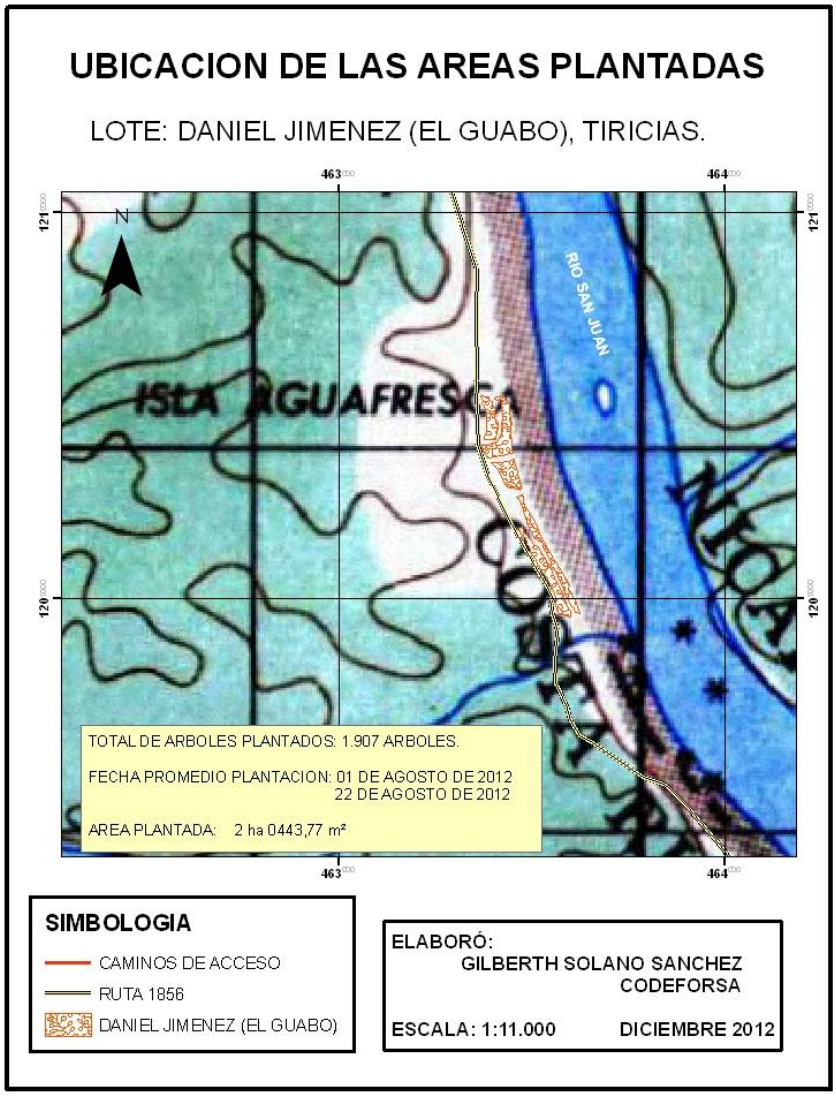
GRUPOS DE VOLUNTARIOS QUE PARTICIPARON EN LA SIEMBRA DE ÁRBOLES		
Actividad	Fecha	Lugar de siembra
Voluntarios meseta central, funcionarios MINAET Sarapiquí	05/08/2012	Boca Caño La Ceiba
Voluntarios meseta central	12/08/2012	Boca del Río Sarapiquí
Funcionarios PONAFIFO, Grupo Guías y Scouts Cartago	18/08/2012	Boca Caño La Ceiba
Voluntarios meseta central, estudiantes del Liceo rural Las Marías y escuela Boca La Ceiba	19/08/2012	Boca Caño La Ceiba, escuela La Ceiba.
Voluntarios Zona Norte	23/08/2012	Boca del Río San Carlos
Voluntarios Zona Norte, Colegio Salmo, funcionarios ACAHN	25/08/2012	Boca del Río San Carlos
Funcionarios SINAC central	30/08/2012	Delta Costa Rica
Colegio El Concho de Pocosol	22/08/2012	Tiricias
Colegio Salmo, voluntarios Zona Norte	23/08/2012	Boca del Río San Carlos
Colegio La Guaria de Pocosol	29/08/2012	Tiricias
Escuela San Isidro de Pocosol	04/09/2012	Tiricias
Colegios Boca Tapada, Boca Río San Carlos	05/09/2012	Boca del Río San Carlos
Escuela Llano Verde y escuela Las Tiricias	11/09/2012	Tiricias, Mojón 2
Grupo de Jóvenes Fuerza Juvenil de Ciudad Quesada	29/09/2012	Boca del Río San Carlos
Escuela El Concho y Escuela Banderas de Pocosol	02/10/2012	Tiricias, Mojón 2
Colegio Banderas de Pocosol	04/10/2012	Tiricias, Mojón 2
Colegio Gastón Peralta de Altamira	11/10/2012	Boca del Río San Carlos
Colegio Técnico de Pital	18/10/2012	Boca del Río San Carlos
Colegio Técnico de Aguas Zarcas	23/10/2012	Boca del Río San Carlos

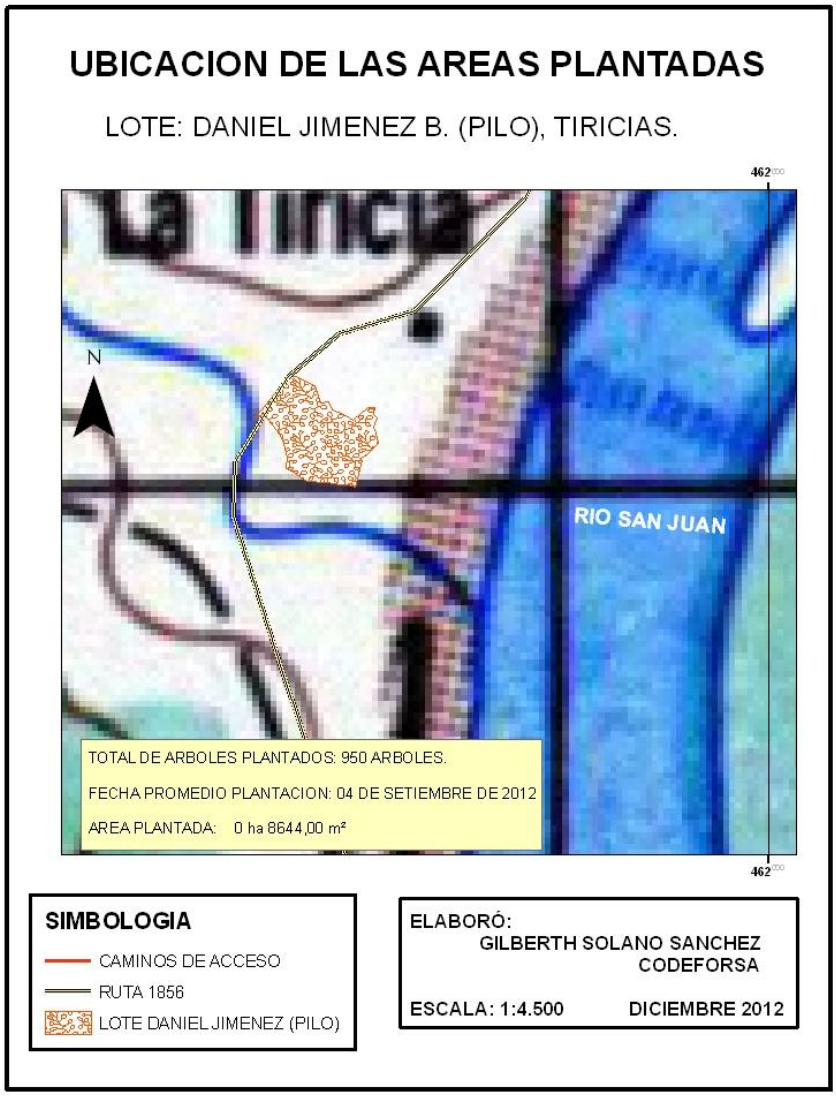
APPENDIX 2: MAPS OF THE AREAS PLANTED

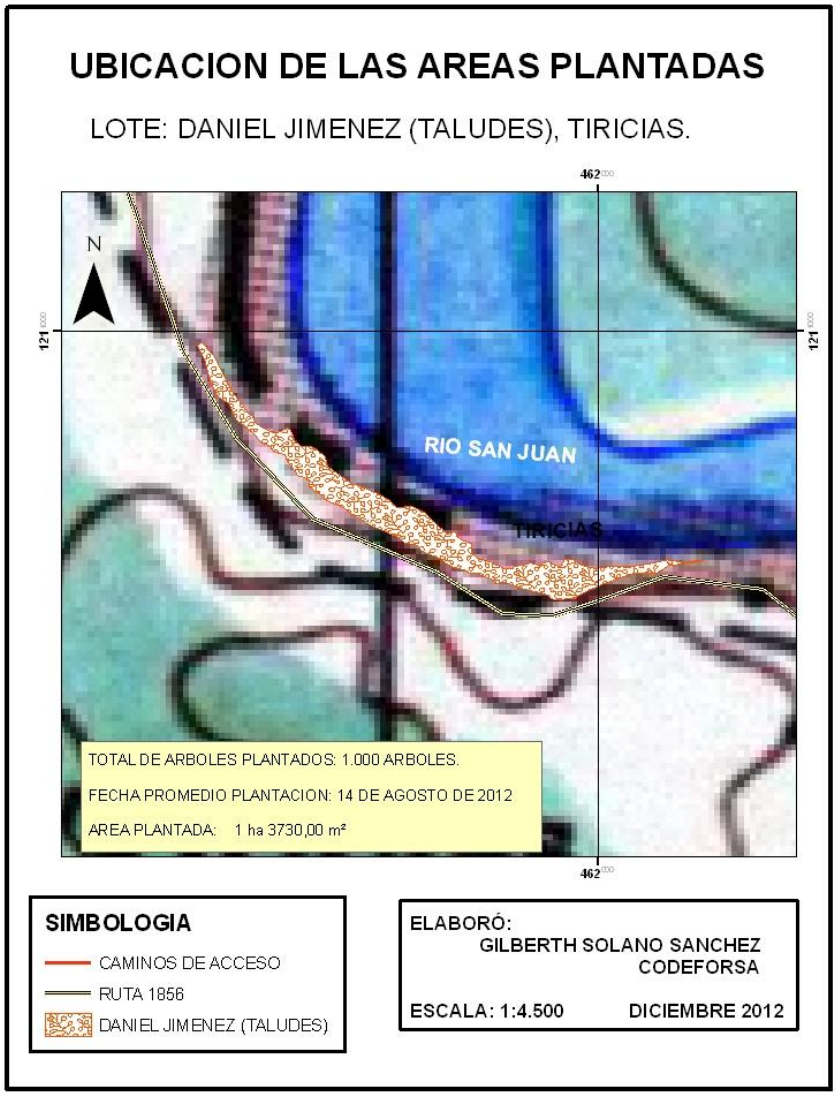
TOTAL TREES PLANTED, AVERAGE PLANTING DATE, PLANTED AREA

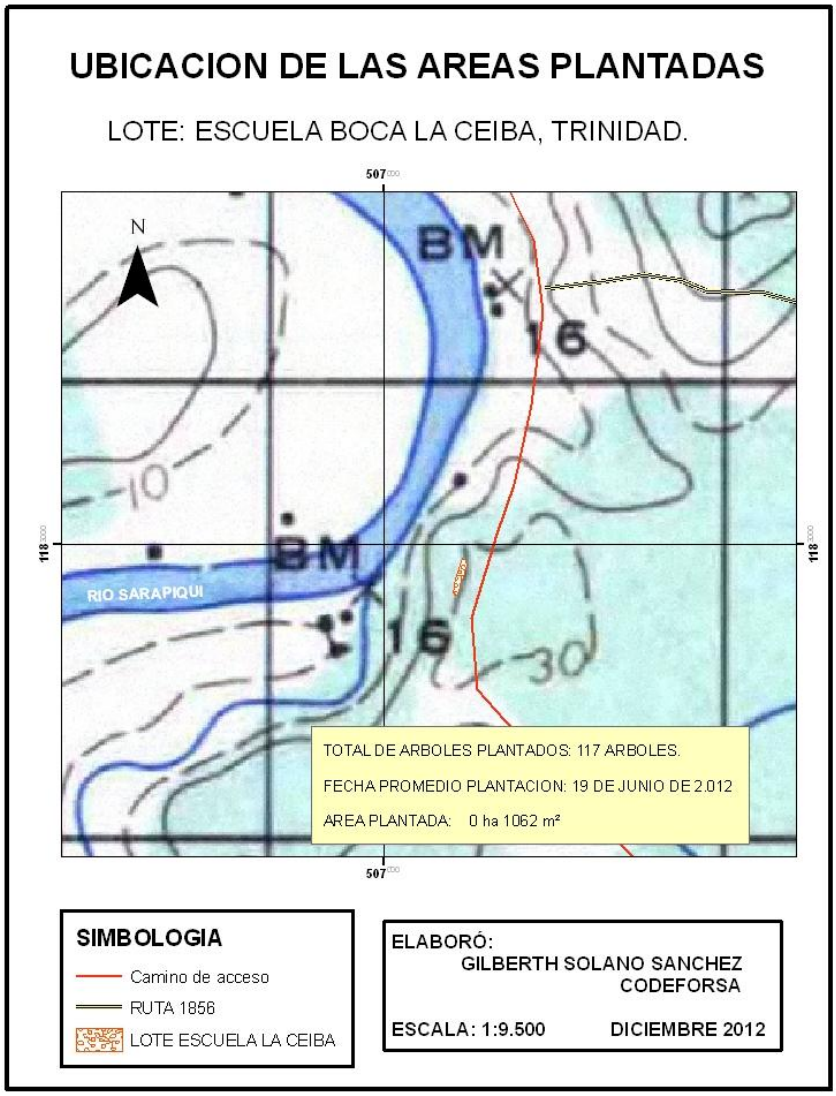
KEY: Access roads; Ruta 1856; Plot location Scale 1:4.500

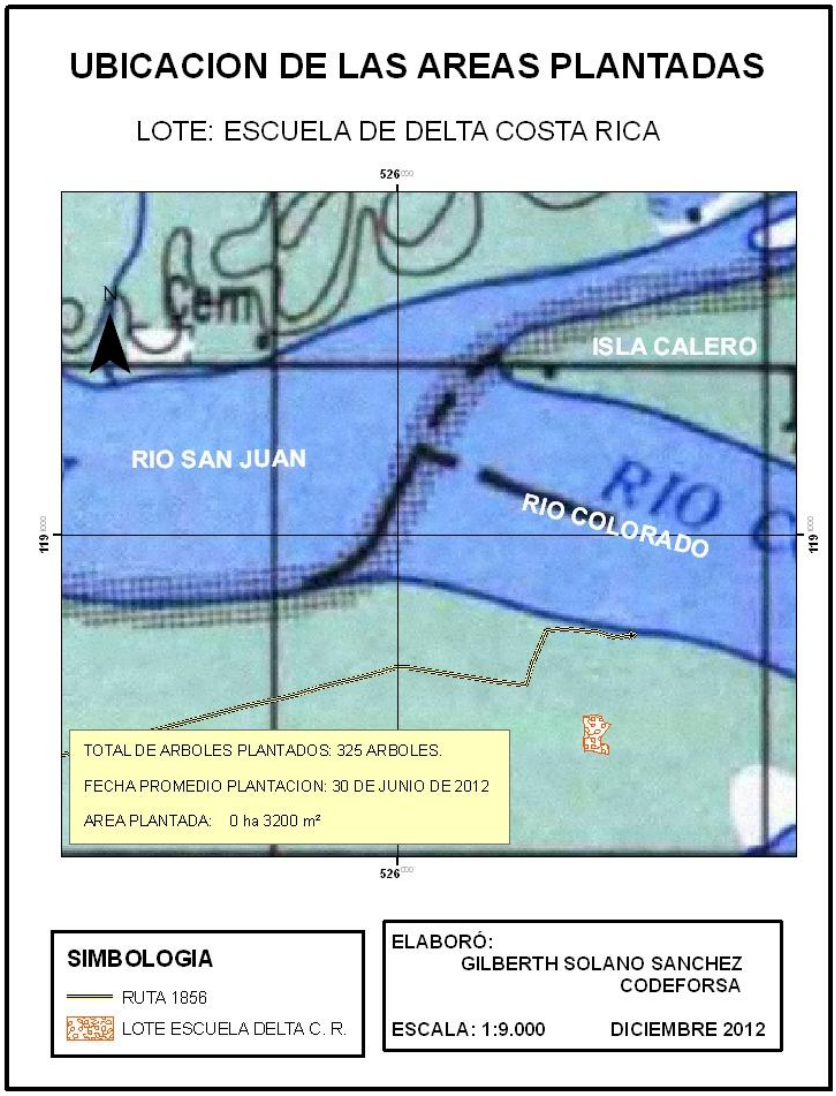

UBICACION DE LAS AREAS PLANTADAS
LOTE: DANIEL JIMENEZ B. (BISMARK), TIRICIAS.
462
121
N
La Tiricia
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 1.280 ARBOLES.
FECHA PROMEDIO PLANTACION: 29 DE AGOSTO DE 2012
AREA PLANTADA: 1 ha 7004,00 m²
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE DANIEL JIMENEZ (BISMARK)
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:5.000
DICIEMBRE 2012

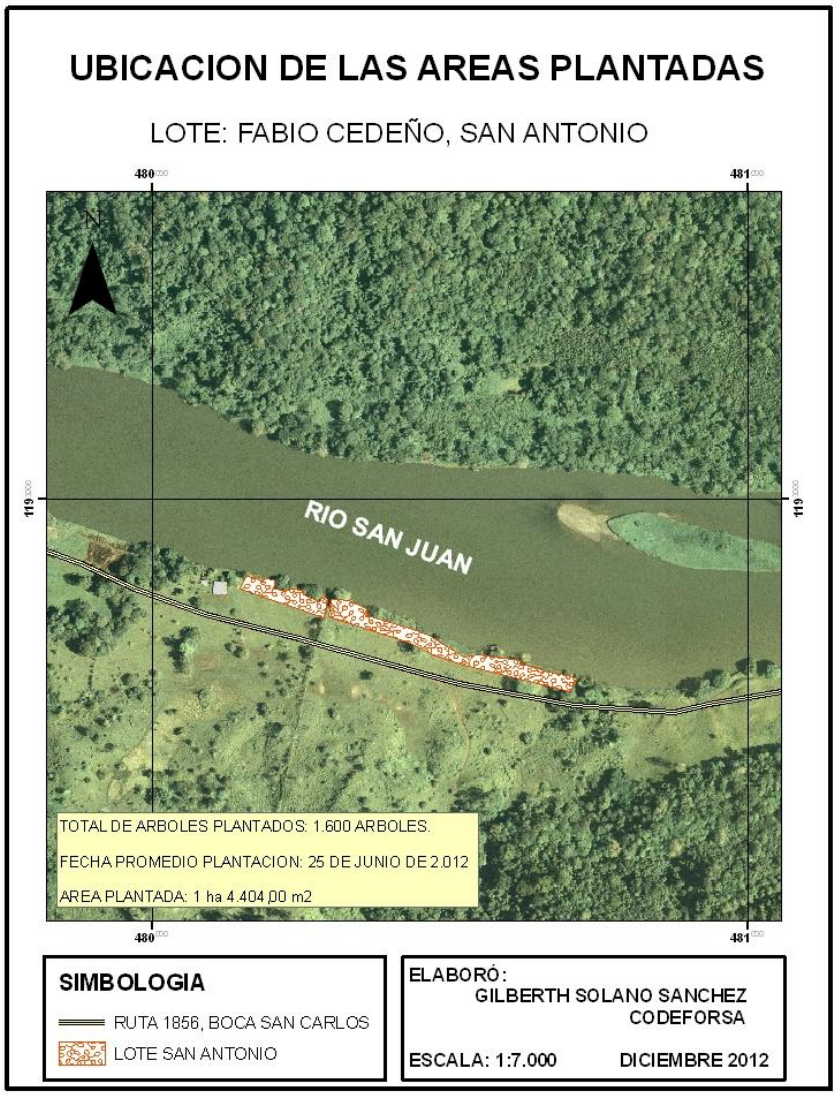

UBICACION DE LAS AREAS PLANTADAS
LOTE: DANIEL JIMENEZ (EL GUABO), TIRICIAS.
463
464
121
120
N
RIO SAN JUAN
ISLA AGUAFRESCA
TOTAL DE ARBOLES PLANTADOS: 1.907 ARBOLES.
FECHA PROMEDIO PLANTACION: 01 DE AGOSTO DE 2012
22 DE AGOSTO DE 2012
AREA PLANTADA: 2 ha 0443,77 m²
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
DANIEL JIMENEZ (EL GUABO)
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:11.000
DICIEMBRE 2012

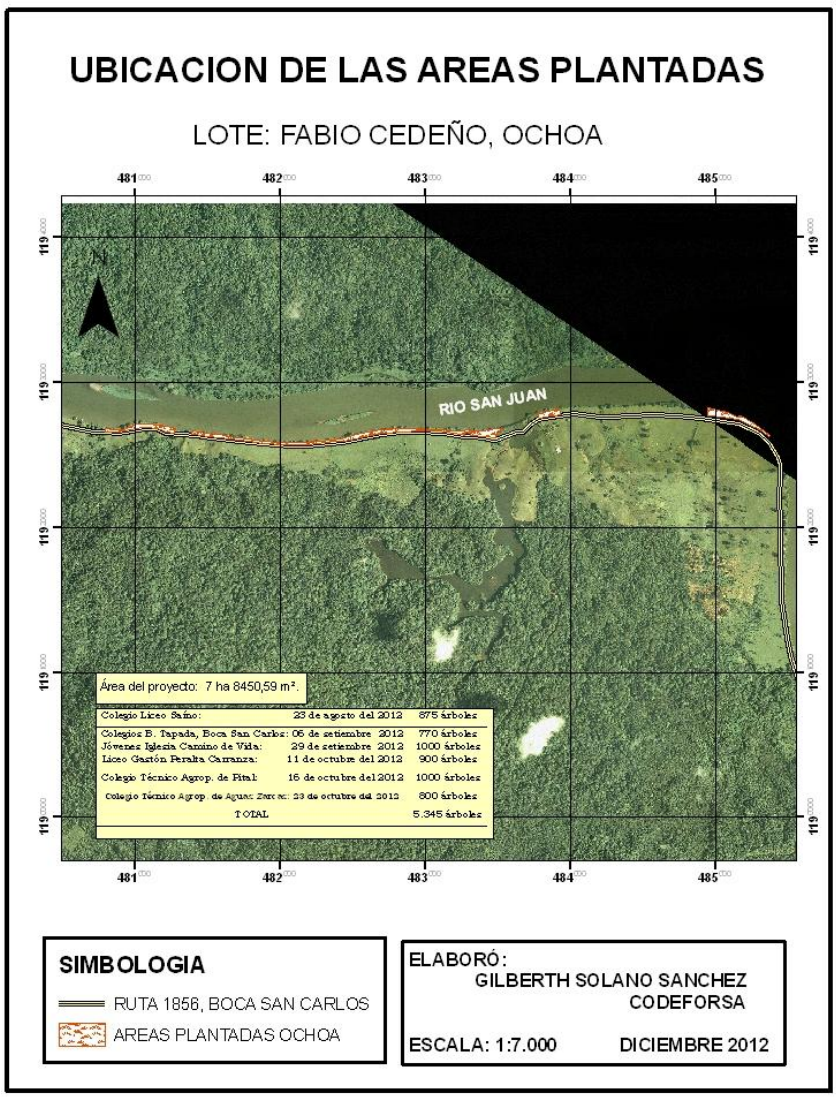

UBICACION DE LAS AREAS PLANTADAS
LOTE: DANIEL JIMENEZ B. (PILO), TIRICIAS.
462000
La Tiricia
N
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 950 ARBOLES.
FECHA PROMEDIO PLANTACION: 04 DE SETIEMBRE DE 2012
AREA PLANTADA: 0 ha 8644,00 m²
462000
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE DANIEL JIMENEZ (PILO)
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:4.500
DICIEMBRE 2012

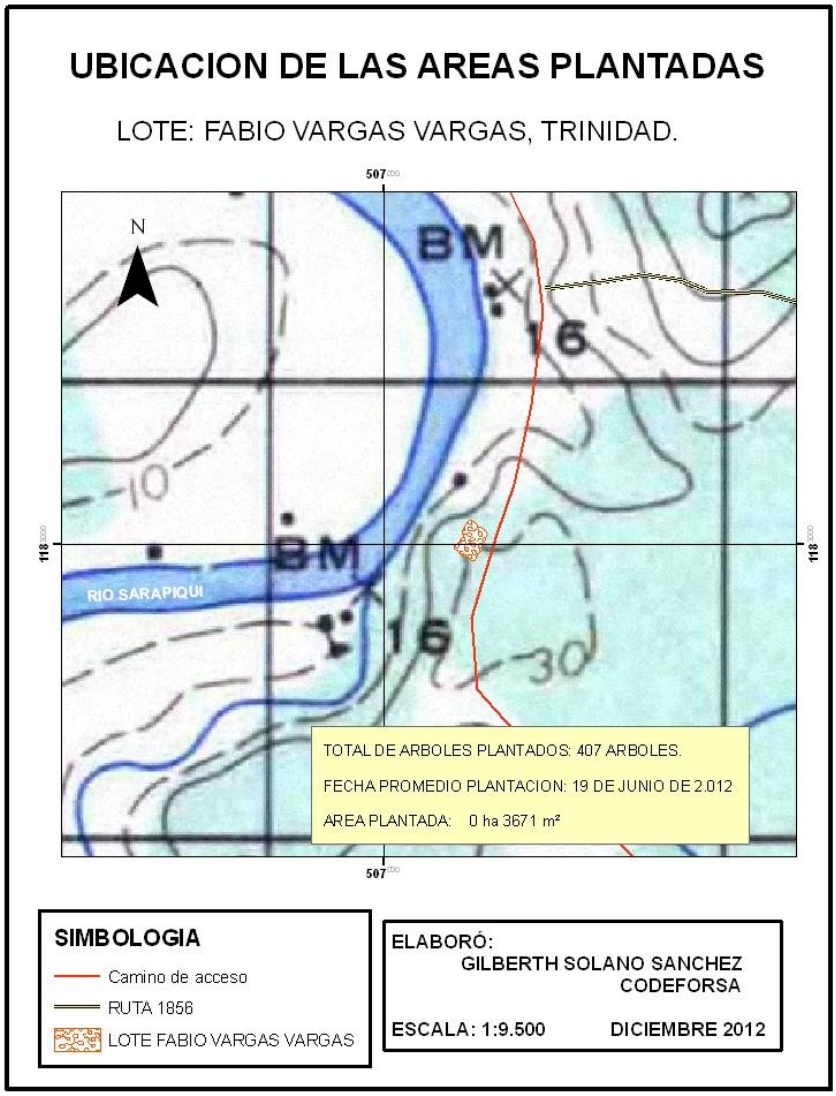

UBICACION DE LAS AREAS PLANTADAS
LOTE: DANIEL JIMENEZ (TALUDES), TIRICIAS.
462
N
121
121
RIO SAN JUAN
TIRICIAS
TOTAL DE ARBOLES PLANTADOS: 1.000 ARBOLES.
FECHA PROMEDIO PLANTACION: 14 DE AGOSTO DE 2012
AREA PLANTADA: 1 ha 3730,00 m²
462
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
DANIEL JIMENEZ (TALUDES)
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:4.500
DICIEMBRE 2012

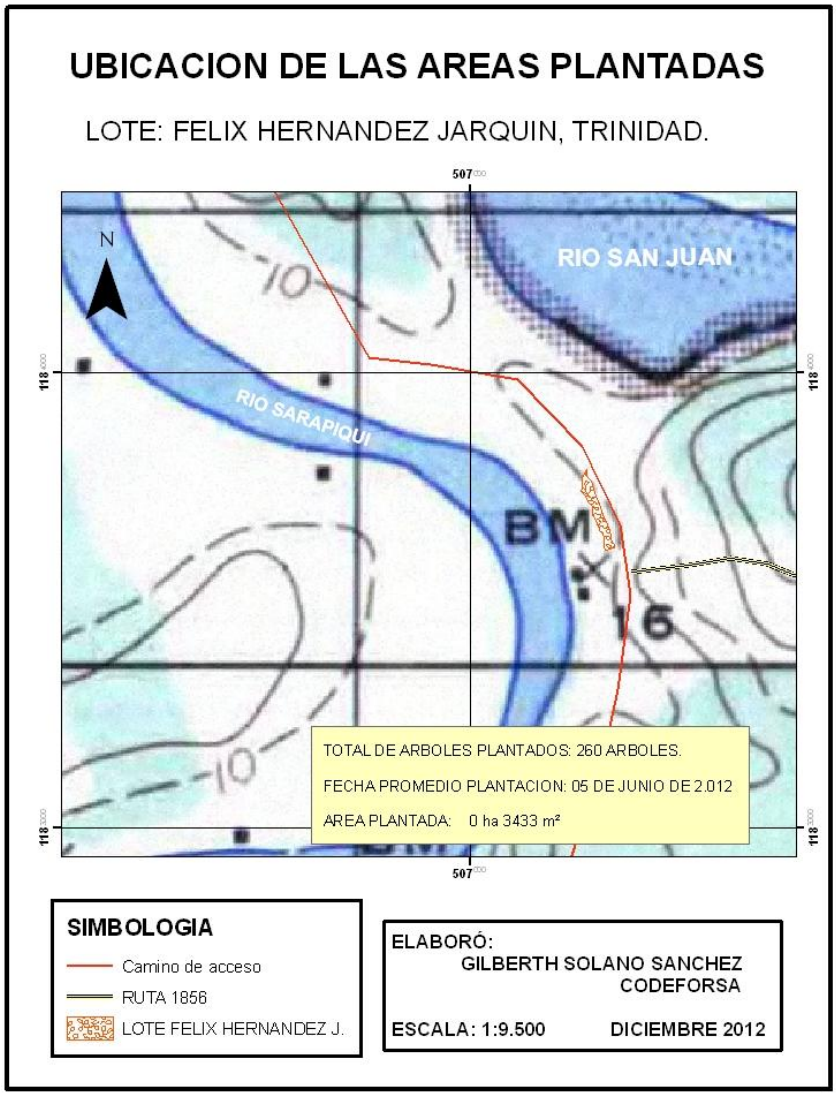

UBICACION DE LAS AREAS PLANTADAS
LOTE: ESCUELA BOCA LA CEIBA, TRINIDAD.
507
118
N
BM
16
10
BM
RIO SARAPIQUI
16
30
TOTAL DE ARBOLES PLANTADOS: 117 ARBOLES.
FECHA PROMEDIO PLANTACION: 19 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 1062 m²
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE ESCUELA LA CEIBA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

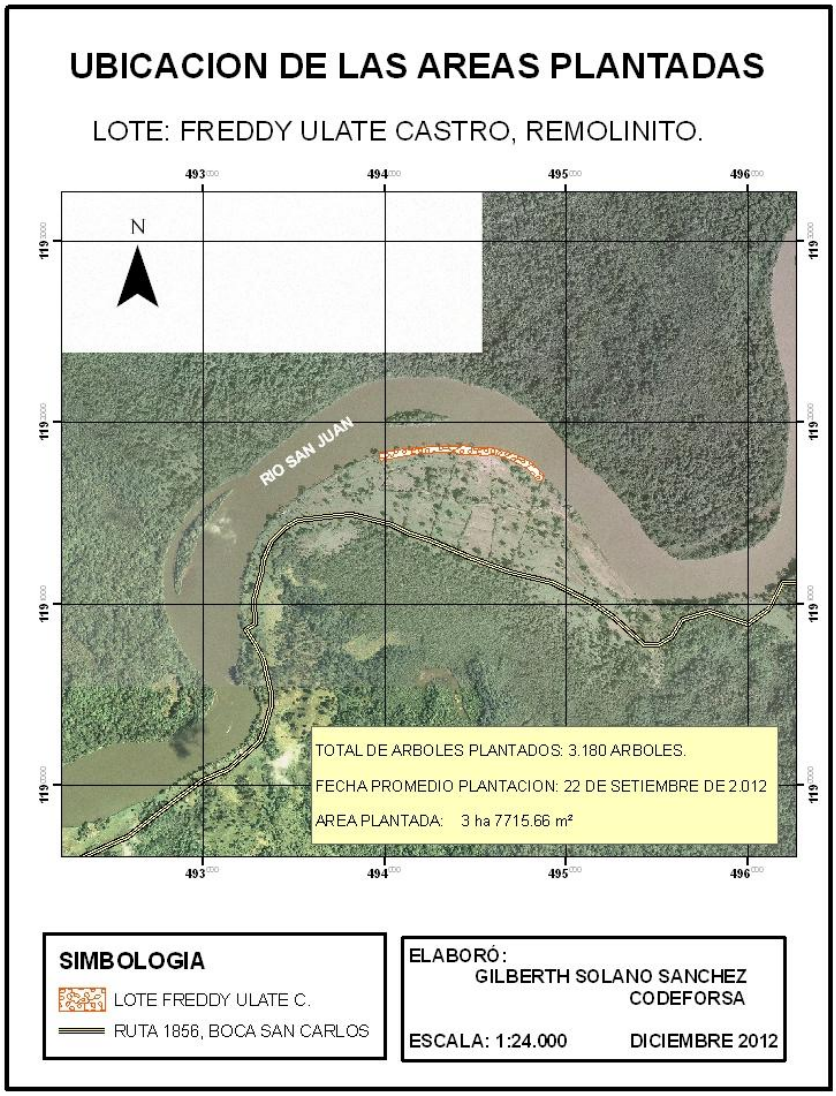

UBICACION DE LAS AREAS PLANTADAS
LOTE: ESCUELA DE DELTA COSTA RICA
526
119
Cem
ISLA CALERO
RIO SAN JUAN
RIO COLORADO
TOTAL DE ARBOLES PLANTADOS: 325 ARBOLES.
FECHA PROMEDIO PLANTACION: 30 DE JUNIO DE 2012
AREA PLANTADA: 0 ha 3200 m²
SIMBOLOGIA
RUTA 1858
LOTE ESCUELA DELTA C. R.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.000
DICIEMBRE 2012

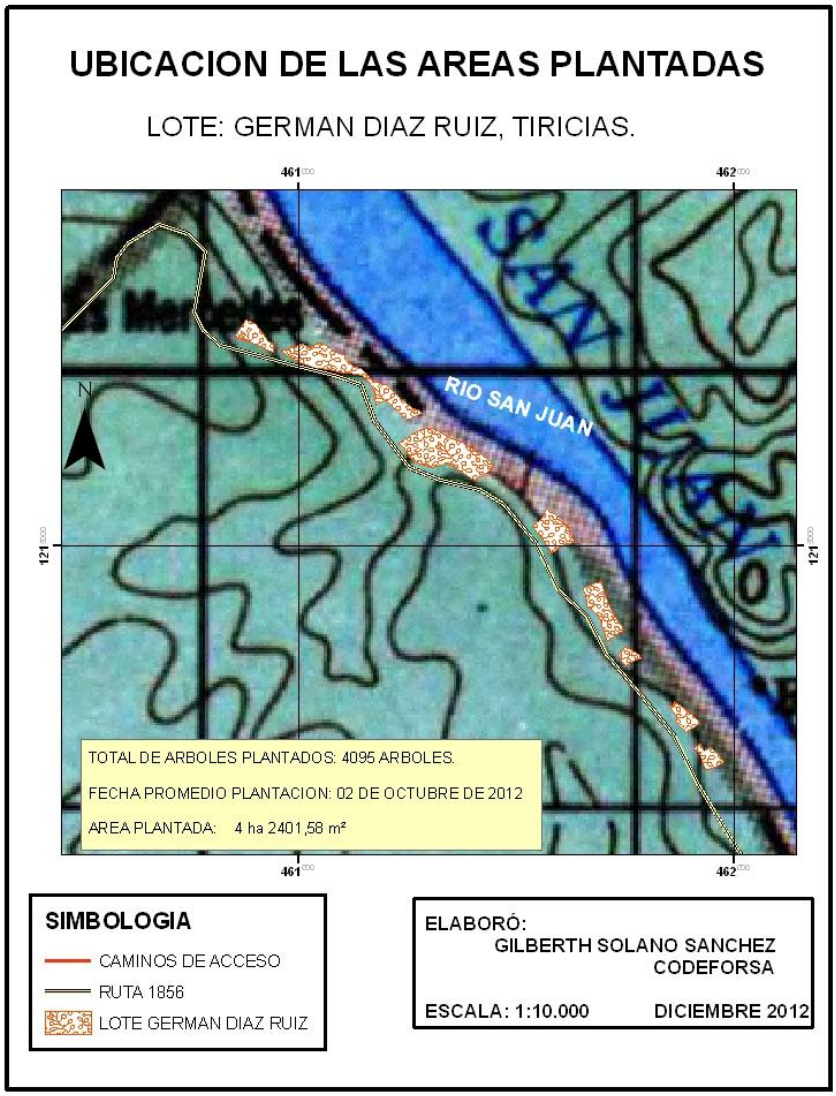

UBICACION DE LAS AREAS PLANTADAS
LOTE: FABIO CEDEÑO, SAN ANTONIO
480
481
N
119
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 1.600 ARBOLES.
FECHA PROMEDIO PLANTACION: 25 DE JUNIO DE 2.012
AREA PLANTADA: 1 ha 4.404,00 m2
SIMBOLOGIA
RUTA 1856, BOCA SAN CARLOS
LOTE SAN ANTONIO
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:7.000
DICIEMBRE 2012

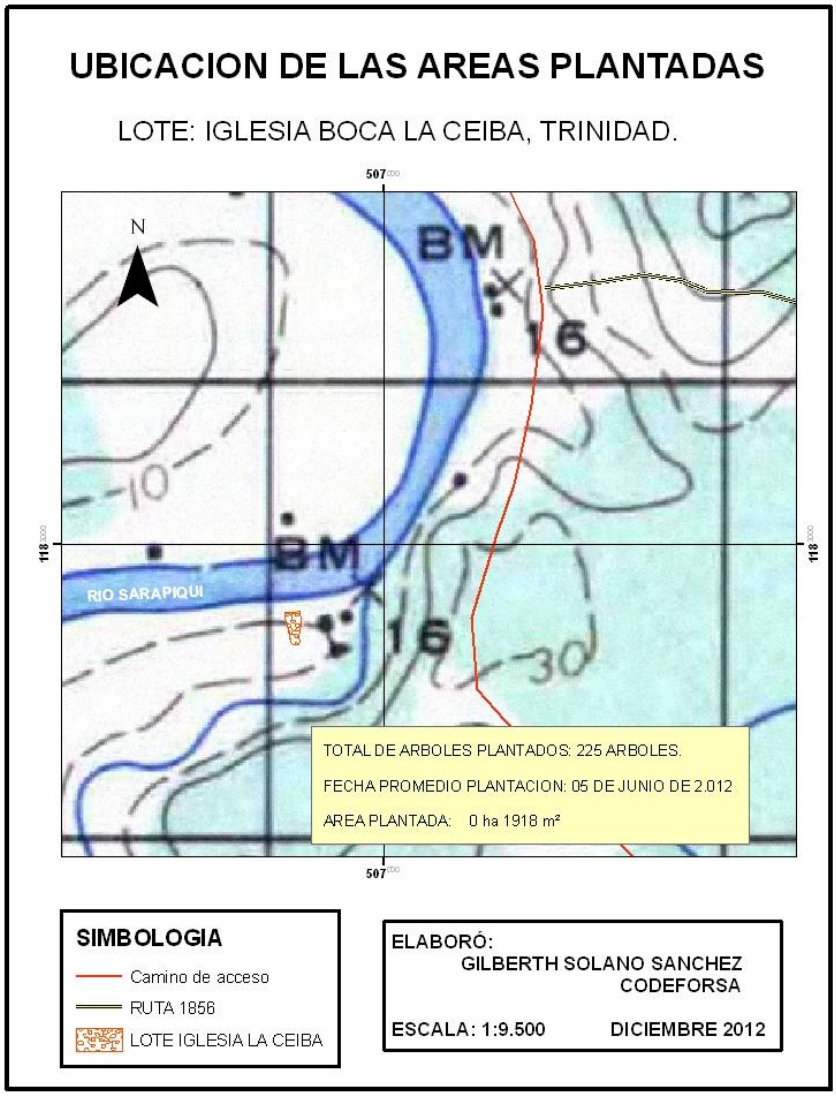

UBICACION DE LAS AREAS PLANTADAS
LOTE: FABIO CEDEÑO, OCHOA
481
482
483
484
485
119
RIO SAN JUAN
Área del proyecto: 7 ha 8450,59 m².
Colegio Liceo Saino: 23 de agosto del 2012 875 árboles
Colegios B. Tapada, Boca San Carlos: 06 de setiembre 2012 770 árboles
Jóvenes Iglesia Camino de Vida: 29 de setiembre 2012 1000 árboles
Liceo Gastón Peralta Carranza: 11 de octubre del 2012 900 árboles
Colegio Técnico Agrop. de Pital: 16 de octubre del 2012 1000 árboles
Colegio Técnico Agrop. de Aguas Zarcas: 23 de octubre del 2012 800 árboles
TOTAL 5.345 árboles
SIMBOLOGIA
RUTA 1856, BOCA SAN CARLOS
AREAS PLANTADAS OCHOA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:7.000
DICIEMBRE 2012

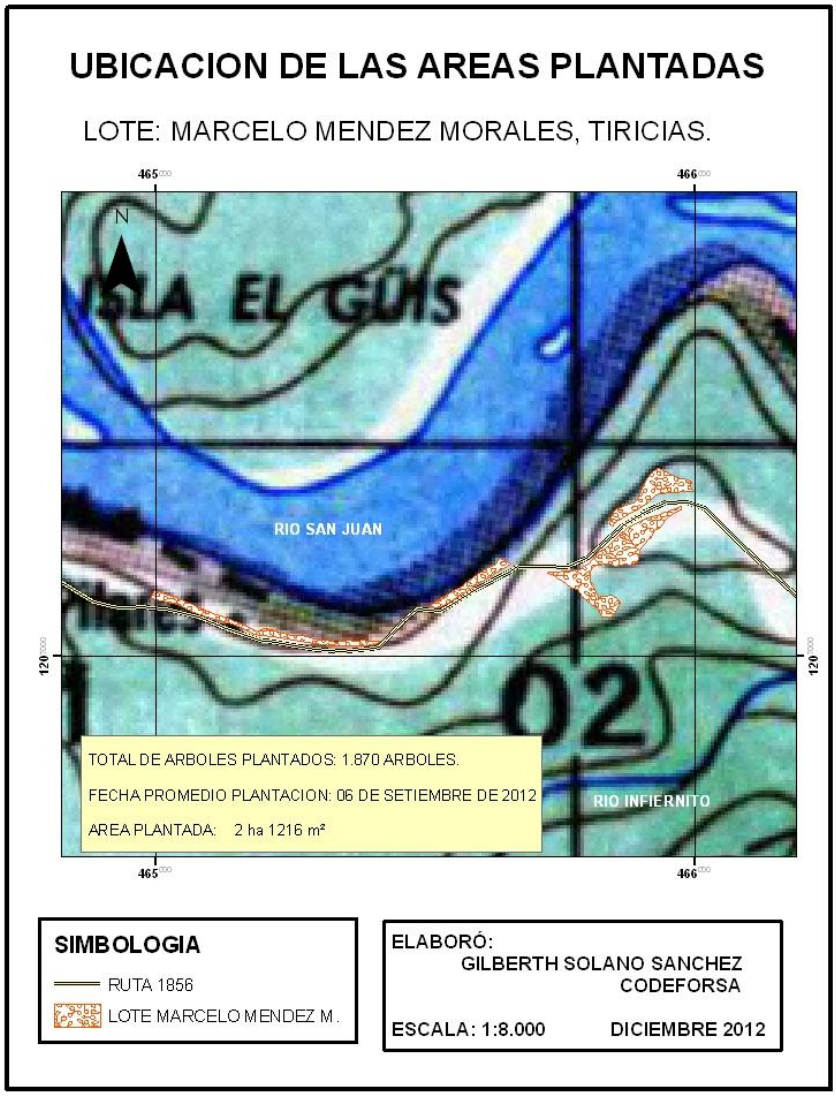

UBICACION DE LAS AREAS PLANTADAS
LOTE: FABIO VARGAS VARGAS, TRINIDAD.
507
N
BM
16
10
BM
RIO SARAPIQUI
16
30
118
118
TOTAL DE ARBOLES PLANTADOS: 407 ARBOLES.
FECHA PROMEDIO PLANTACION: 19 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 3671 m²
507
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE FABIO VARGAS VARGAS
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

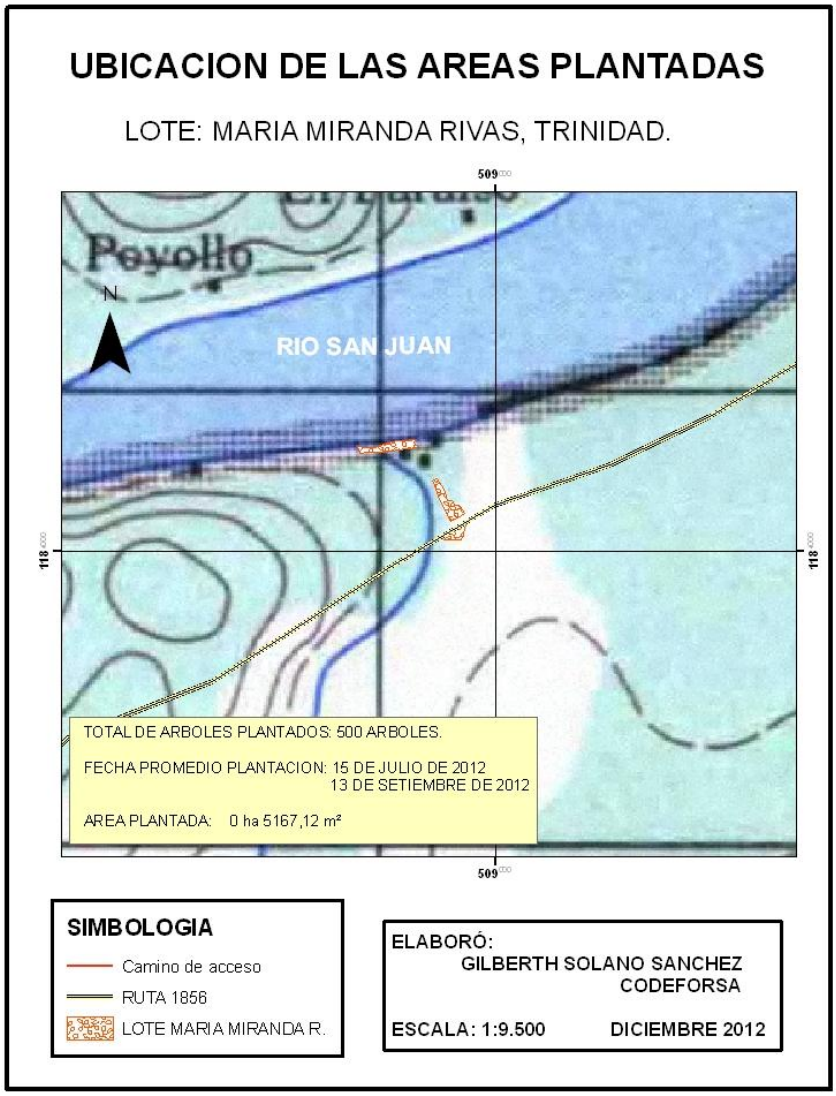

UBICACION DE LAS AREAS PLANTADAS
LOTE: FELIX HERNANDEZ JARQUIN, TRINIDAD.
507
118
N
RIO SAN JUAN
RIO SARAPIQUI
BM
16
10
TOTAL DE ARBOLES PLANTADOS: 260 ARBOLES.
FECHA PROMEDIO PLANTACION: 05 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 3433 m²
SIMBOLOGIA
Camino de acceso
RUTA 1858
LOTE FELIX HERNANDEZ J.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

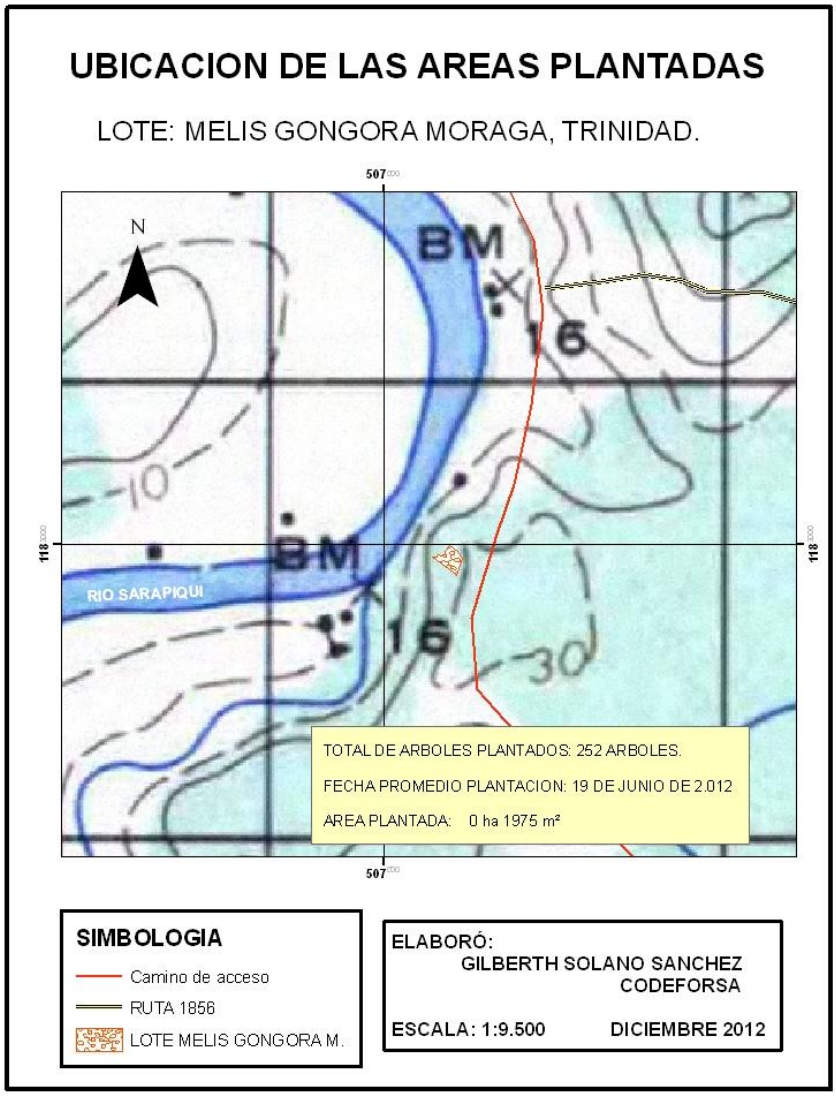

UBICACION DE LAS AREAS PLANTADAS
LOTE: FREDDY ULATE CASTRO, REMOLINITO.
493
494
495
496
N
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 3.180 ARBOLES.
FECHA PROMEDIO PLANTACION: 22 DE SETIEMBRE DE 2.012
AREA PLANTADA: 3 ha 7715.66 m²
SIMBOLOGIA
LOTE FREDDY ULATE C.
RUTA 1856, BOCA SAN CARLOS
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:24.000
DICIEMBRE 2012

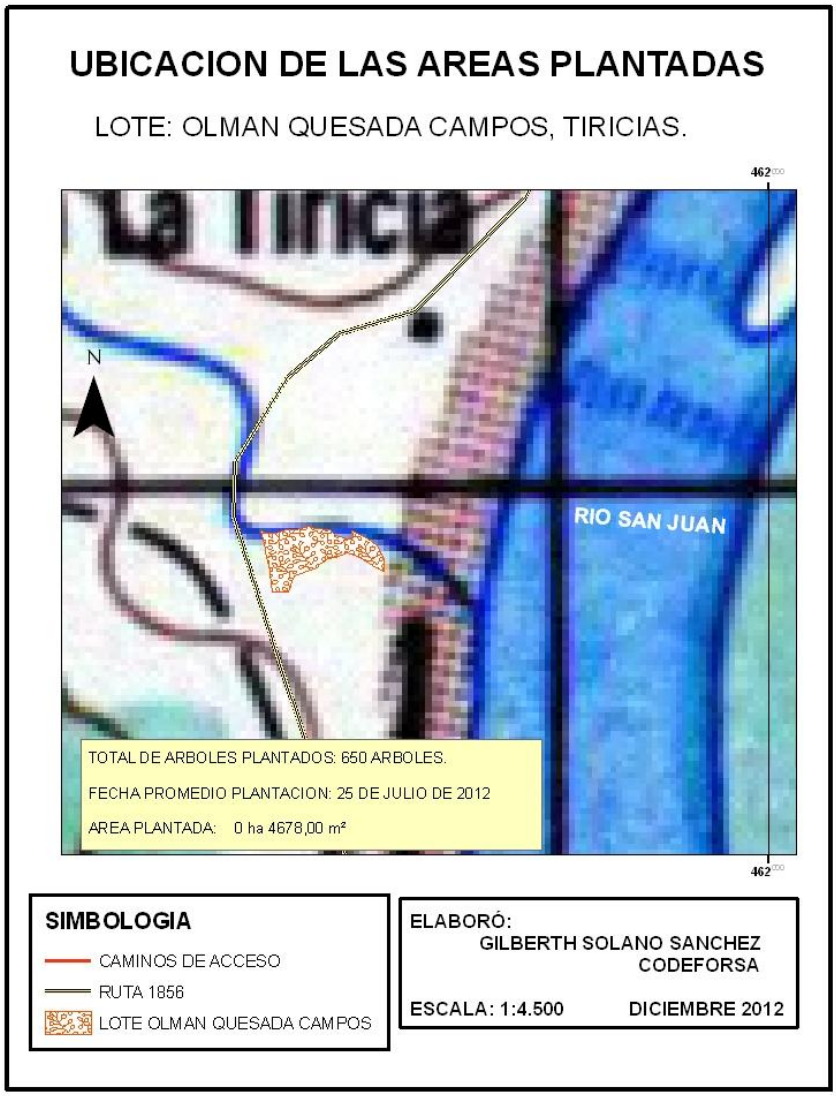

UBICACION DE LAS AREAS PLANTADAS
LOTE: GERMAN DIAZ RUIZ, TIRICIAS.
461
462
121
RIO SAN JUAN
N
TOTAL DE ARBOLES PLANTADOS: 4095 ARBOLES.
FECHA PROMEDIO PLANTACION: 02 DE OCTUBRE DE 2012
AREA PLANTADA: 4 ha 2401,58 m²
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE GERMAN DIAZ RUIZ
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:10.000
DICIEMBRE 2012

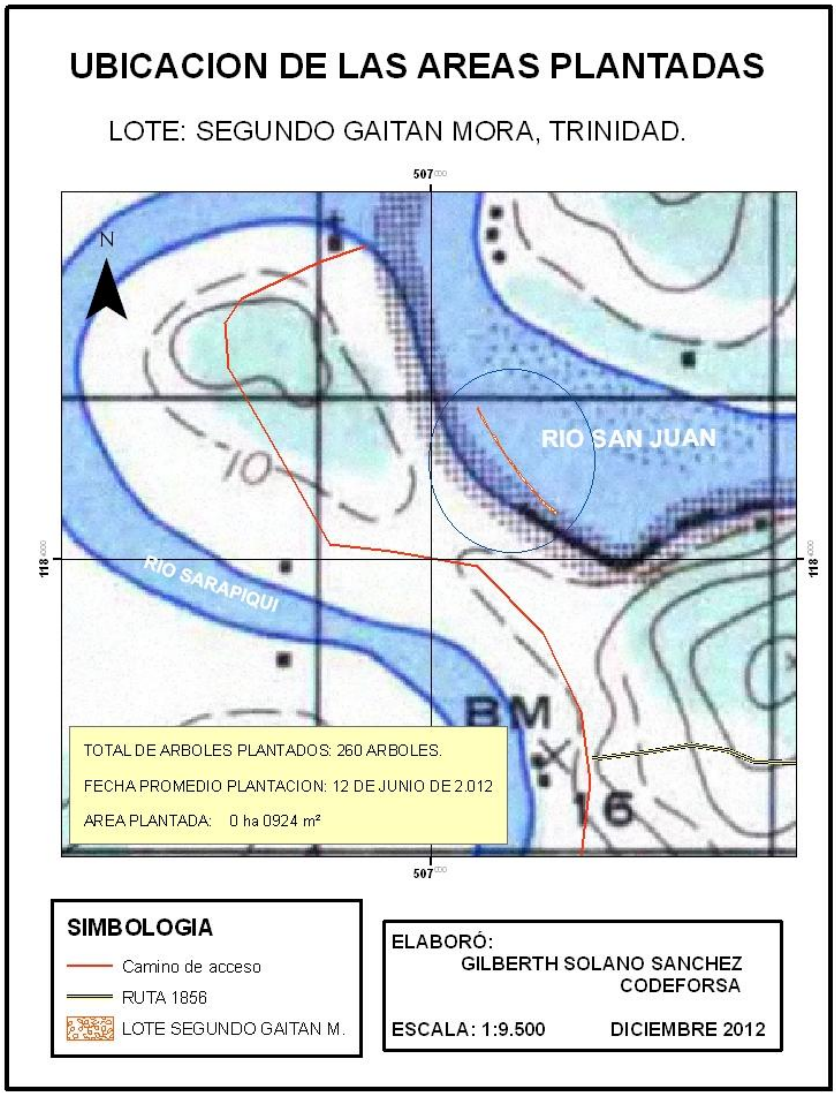

UBICACION DE LAS AREAS PLANTADAS
LOTE: IGLESIA BOCA LA CEIBA, TRINIDAD.
507
N
BM
16
10
BM
RIO SARAPIQUI
16
30
118
118
TOTAL DE ARBOLES PLANTADOS: 225 ARBOLES.
FECHA PROMEDIO PLANTACION: 05 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 1918 m²
507
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE IGLESIA LA CEIBA
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012

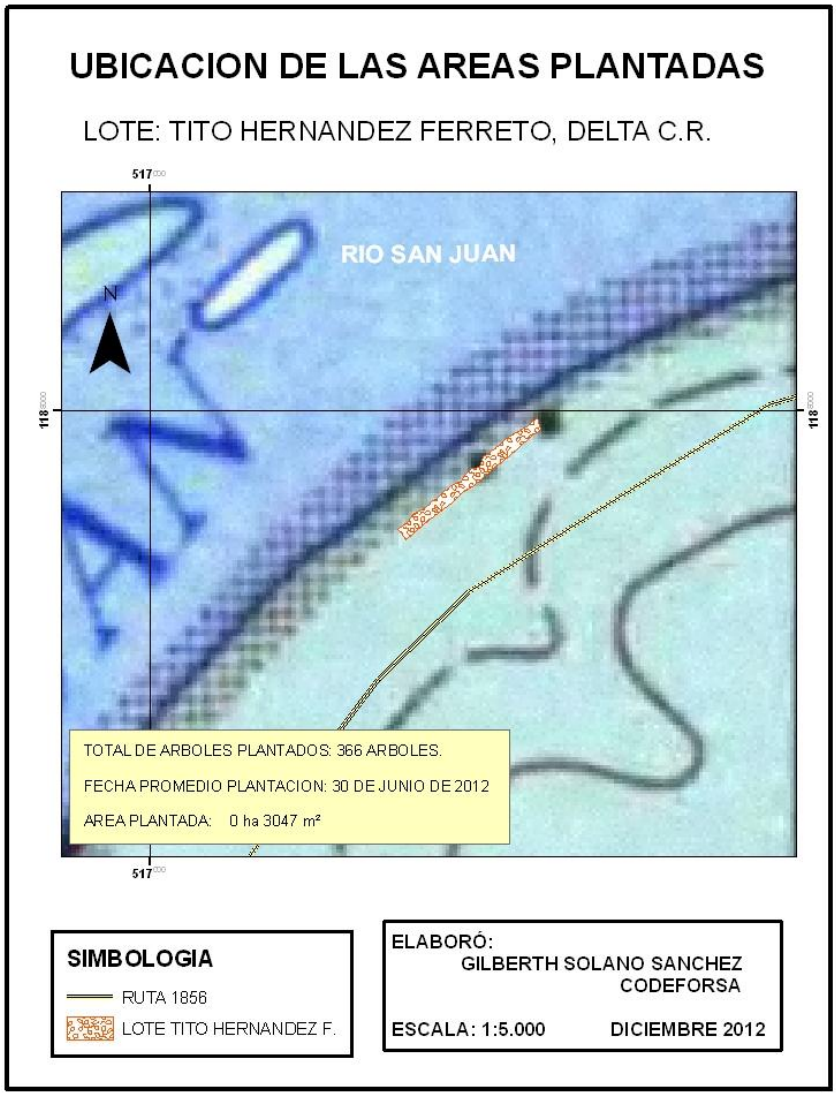

UBICACION DE LAS AREAS PLANTADAS
LOTE: MARCELO MENDEZ MORALES, TIRICIAS.
465000
466000
N
ISLA EL GUIS
RIO SAN JUAN
02
120000
TOTAL DE ARBOLES PLANTADOS: 1.870 ARBOLES.
FECHA PROMEDIO PLANTACION: 06 DE SETIEMBRE DE 2012
AREA PLANTADA: 2 ha 1216 m²
RIO INFIERNITO
SIMBOLOGIA
RUTA 1856
LOTE MARCELO MENDEZ M.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:8.000
DICIEMBRE 2012

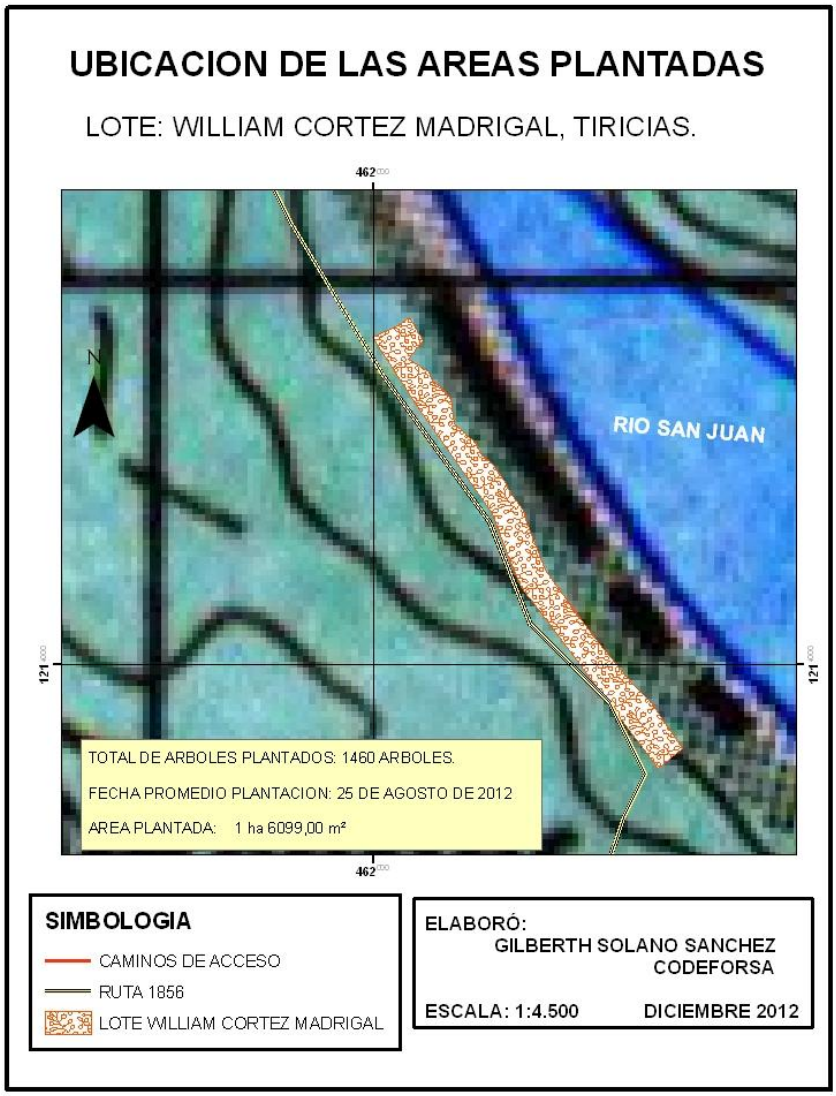

UBICACION DE LAS AREAS PLANTADAS
LOTE: MARIA MIRANDA RIVAS, TRINIDAD.
509
Peyollo
N
RIO SAN JUAN
118
118
TOTAL DE ARBOLES PLANTADOS: 500 ARBOLES.
FECHA PROMEDIO PLANTACION: 15 DE JULIO DE 2012
13 DE SETIEMBRE DE 2012
AREA PLANTADA: 0 ha 5167,12 m²
509
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE MARIA MIRANDA R.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012


UBICACION DE LAS AREAS PLANTADAS
LOTE: MELIS GONGORA MORAGA, TRINIDAD.
507
118
N
BM
16
10
BM
RIO SARAPIQUI
16
30
TOTAL DE ARBOLES PLANTADOS: 252 ARBOLES.
FECHA PROMEDIO PLANTACION: 19 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 1975 m²
SIMBOLOGIA
Camino de acceso
RUTA 1856
LOTE MELIS GONGORA M.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012


UBICACION DE LAS AREAS PLANTADAS
LOTE: OLMAN QUESADA CAMPOS, TIRICIAS.
462000
N
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 650 ARBOLES.
FECHA PROMEDIO PLANTACION: 25 DE JULIO DE 2012
AREA PLANTADA: 0 ha 4678,00 m²
462000
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE OLMAN QUESADA CAMPOS
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:4.500
DICIEMBRE 2012


UBICACION DE LAS AREAS PLANTADAS
LOTE: SEGUNDO GAITAN MORA, TRINIDAD.
507
N
RIO SAN JUAN
RIO SARAPIQUI
BM
16
118
TOTAL DE ARBOLES PLANTADOS: 260 ARBOLES.
FECHA PROMEDIO PLANTACION: 12 DE JUNIO DE 2.012
AREA PLANTADA: 0 ha 0924 m²
SIMBOLOGIA
Camino de acceso
RUTA 1858
LOTE SEGUNDO GAITAN M.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:9.500
DICIEMBRE 2012


UBICACION DE LAS AREAS PLANTADAS
LOTE: TITO HERNANDEZ FERRETO, DELTA C.R.
517
RIO SAN JUAN
N
118
TOTAL DE ARBOLES PLANTADOS: 366 ARBOLES.
FECHA PROMEDIO PLANTACION: 30 DE JUNIO DE 2012
AREA PLANTADA: 0 ha 3047 m²
SIMBOLOGIA
RUTA 1856
LOTE TITO HERNANDEZ F.
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:5.000
DICIEMBRE 2012


UBICACION DE LAS AREAS PLANTADAS
LOTE: WILLIAM CORTEZ MADRIGAL, TIRICIAS.
462
121
N
RIO SAN JUAN
TOTAL DE ARBOLES PLANTADOS: 1460 ARBOLES.
FECHA PROMEDIO PLANTACION: 25 DE AGOSTO DE 2012
AREA PLANTADA: 1 ha 6099,00 m²
SIMBOLOGIA
CAMINOS DE ACCESO
RUTA 1856
LOTE WILLIAM CORTEZ MADRIGAL
ELABORÓ:
GILBERTH SOLANO SANCHEZ
CODEFORSA
ESCALA: 1:4.500
DICIEMBRE 2012

APPENDIX 3: VISIT TO THE SLOPES BEFORE AND AFTER PLANTING OF THE VEGETATION COVER

SLOPE No. 1

BEFORE	AFTER

BEFORE	AFTER

SLOPE No. 2

BEFORE	AFTER

This slope had a geomembrane cover that was stolen by unknown persons.

SLOPE No. 3

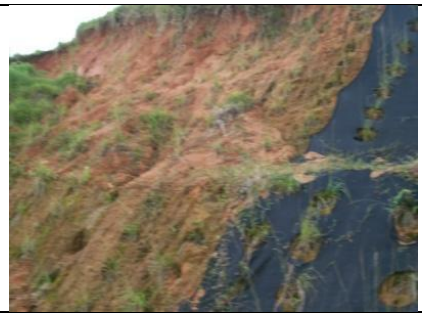
BEFORE	AFTER

SLOPE No. 4

BEFORE	AFTER

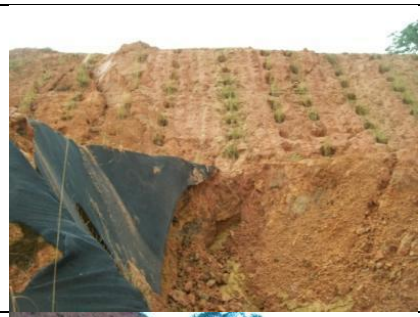
SLOPE No. 5

BEFORE	AFTER

BEFORE	AFTER
	

SLOPE No. 6

BEFORE	AFTER

BEFORE	AFTER
	

SLOPE No. 7

BEFORE	AFTER

BEFORE	AFTER

ANNEX 3

Allan Astorga G. and Andreas Mende

Route 1856: Analysis of the Change in Land use Based on Satellite Images Before and After the Construction of the Border Road

August 2013

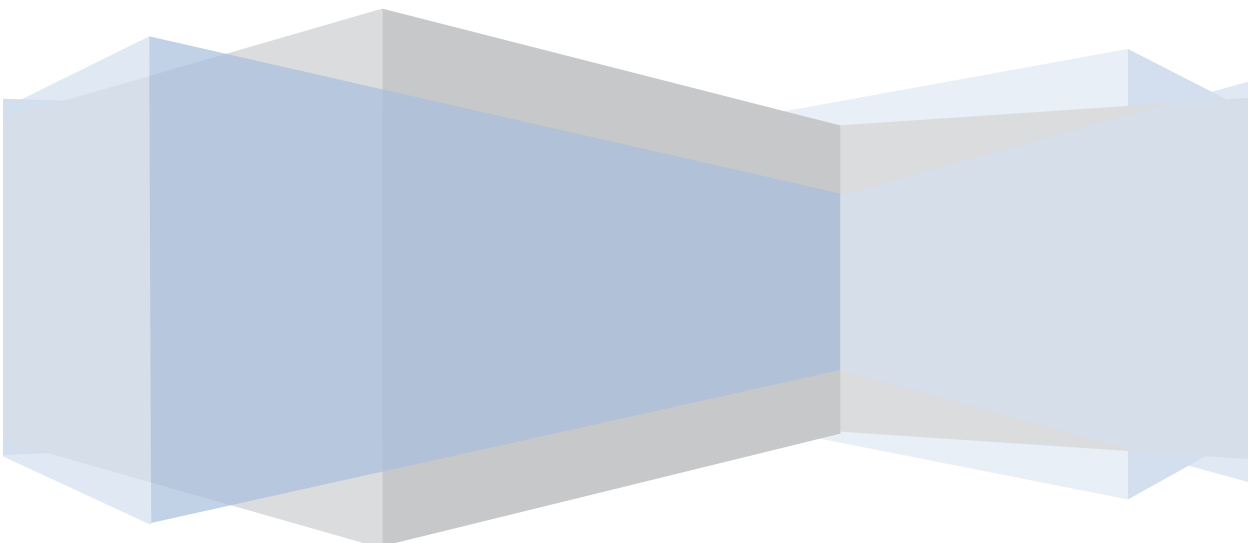
Astorga & Mende (2013)

Route 1856: analysis of the change in land use

Based on satellite images before and after the construction of the border road

Allan Astorga G. & Andreas Mende

August 2013



Index

Index....2
Foreword....3
1. Introduction....4
1.1 PRESENTATION....4
1.2 OBJECTIVE....5
1.3 METHODOLOGY....5
1.4 ORGANIZATION OF THE DOCUMENT....7
2. Results: net effect of changes in land use....8
2.1 TYPES OF LAND USE....8
2.2 COMPARATIVE MAPS....10
2.3 SUMMARY OF RESULTS....24
3. Conclusions....27
4. References....28

Foreword

This study has been prepared by Dr. Allan Astorga and Dr. Andreas Mende following a request of the Ministry of Foreign Affairs of the Republic of Costa Rica.

Dr. Allan Astorga-Gättgens is a Professor of Sedimentology and Environmental Geology at the University of Costa Rica since 1991, and Consultant in Environmental Impact Assessment, Environmental Management and Environmental Land. He holds the degrees of Licentiate in Geology by the School of Geology at the University of Costa Rica (1987), and Doctor of Natural Sciences by the University of Stuttgart, Germany (1996).

Dr. Andreas Mende is a Consultant and expert in Geographic Information Systems, Remote Sensing, Environmental Geology, Sedimentology and Hydrogeology. He has been Investigator at the University of Costa Rica with a three-year Postdoc-Scholarship from the German Research Foundation (DFG) and works since 2005 as an Independent Consultant based in San José, Costa Rica. He holds a Diploma in Geology by the University of Bonn (Germany) (1995), and a Doctorate in Natural Sciences by the University of Stuttgart, Germany (1999).

1. Introduction

1.1 PRESENTATION

Based on the circumstances that surrounded the initial construction of Route 1856 and the need for an accurate assessment of the "effect of the change in land use" that it brought about, a need arose to perform an analysis of this change. Said analysis is documented herein.

Figure 1 presents the approximate geographic location of Route 1856, built as a border road that communicates the area of Los Chiles to the Delta of the Colorado River (Delta CR) sector in the northern sector of Costa Rica.

It is important to clarify that this analysis focuses on the change of land use in the portion of Route 1856 that runs parallel to the San Juan River, that is, between Marker 2 and Delta CR. It seeks to perform a quantitative assessment of the net effects produced in the different ecosystems present in the area (see **Figure 2**). The full length of Route 1856 from Los Chiles to Delta CR is 159.7 km, while from Marker 2 to Delta CR it is 108.2 km. The latter is the length of road covered by this study.

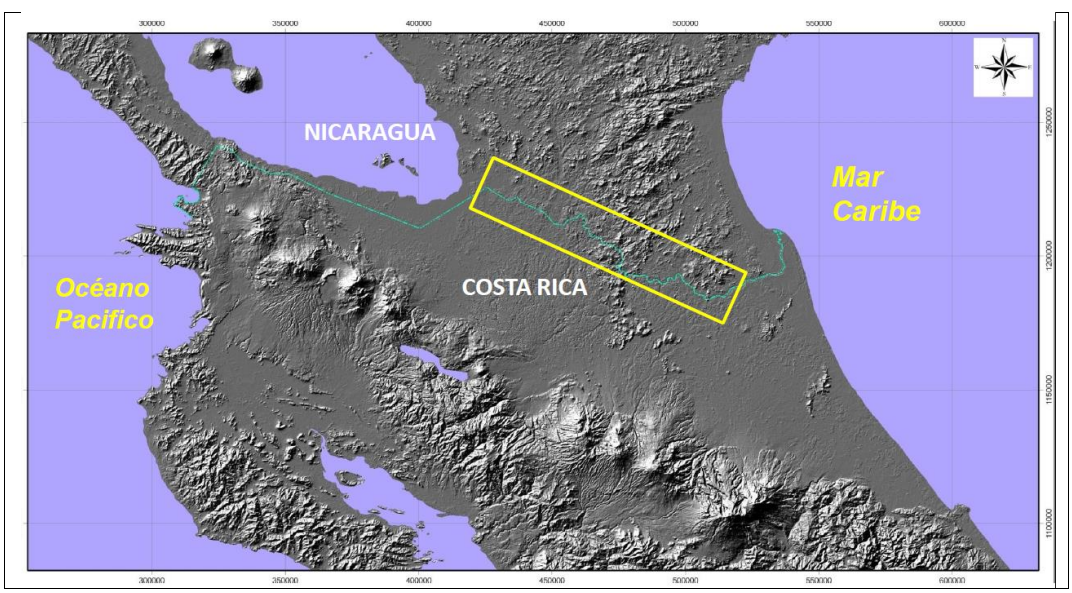


***Fig. 1**. Map of the approximate geographic location of Route 1856*

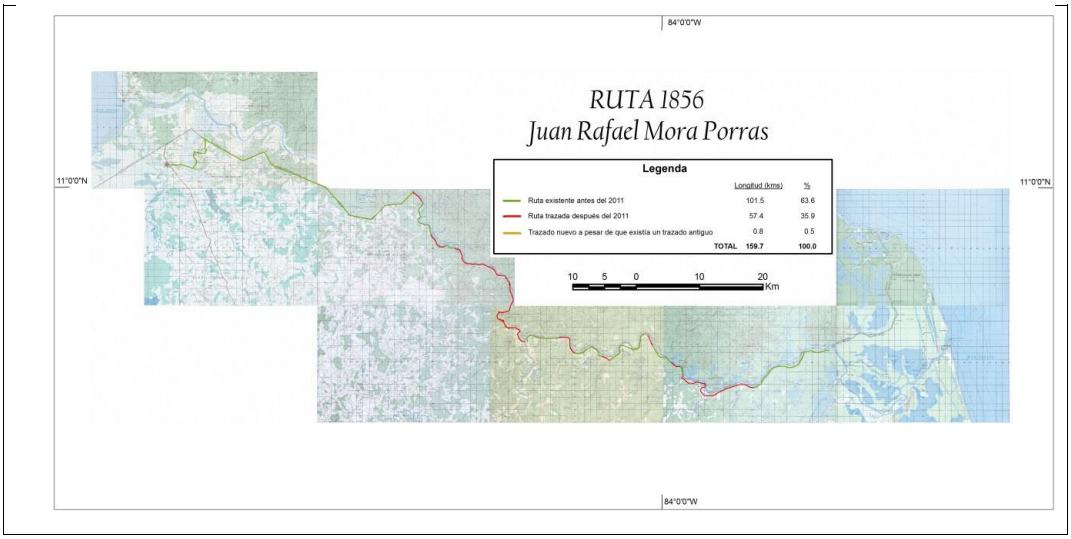


***Fig. 2**. Portion of Route 1856 subject to this analysis of change in land use. Map based on the topographic sheets with scale 1:50.000 according to the Costa Rican National Institute of Geography.*

1.2 OBJECTIVE

The objective of this study is to perform a comparative analysis of land use, following a standardized method, based on information obtained from satellite images taken before and after the construction of Route 1856 in 2011, using a Geographic Information System to determine the net effect of the change in land use that resulted from the construction of said border road.

1.3 METHODOLOGY

The methodological steps applied for this analysis were the following:

1) Use of a standardized methodology, previously established in Costa Rica through Executive Decree No. 32967 – MINAE, to determine land use in a previously selected area of study, defined as a one-kilometre wide strip measured from the right bank of San Juan River into Costa Rican territory.

2) Development of the topographic basis according to the topographic sheets with scale 1:50.000 of the Costa Rican National Geographic Institute (Instituto Geográfico Nacional de Costa Rica).
3) Interpretation of aerial photos and satellite images, with a resolution ranging from 0.5 - 5 m/pixel, before and after Route 1856, provided by a specialized company and obtained from the Government of Costa Rica.
4) Systematic field verification, including fly-overs and work performed jointly with Forestry Engineer Rafael Bolaños from the Tropical Science Centre (Centro Científico Tropical).
5) Entering of all of the information interpreted into a Geographic Information System.
6) Comparative analysis and generation of statistics for mapping before and after Route 1856.

The satellite images with a resolution of 0.5 to 5.m/pixel, as well as the aerial photographs used as basis for the land use interpretation presented in this study are of a sufficiently high quality to differentiate various details, in particular types of vegetation present in the study area. Moreover, the interpretation obtained from these images was complemented by a systematic field review, which allowed for the information obtained from the images to be verified. The information obtained was processed using a Geographic Information System (GIS), through which it was possible to refine the accuracy of the data and in particular the calculations of the areas shown in **Table 2** (p.23). This methodology makes it possible to specify with accuracies in the order of meters for different types of land use analyzed in Table 2, with an error margin of less than 1 %.

It is worth noting that prior to the construction of Route 1856 there were pre-existing roads in significant parts of its length. Of the total length of the route between Los Chiles and Delta CR, consisting of 159.7 km, there were previously existing rustic roads in 101.5 km (63.6%, see Figure 2). Similarly, the area between Marker 2 and Delta CR, 50.0 km (46.2%) of Route 1856 was built on pre-existing rustic roads. These roads had different characteristics in terms of width and easements, and they joined several villages. Route 1856 was built over this route design. This factor is taken into account in this analysis.

1.4 ORGANIZATION OF THE DOCUMENT

Apart from the introductory chapter, this technical report includes two additional chapters, namely:

- Main results
- Conclusions

2. Results: net effect of changes in land use

2.1 TYPES OF LAND USE

The 15 types of land use identified in the interpretation of photos and satellite images documented in this report are described in **Table 1**.

Furthermore, **Figure 3** presents, for illustrative purposes, an example of the interpretation of land use on a portion of Route 1856 that runs parallel to the right bank of San Juan River. Specific examples of the interpretation of satellite images are provided in **Appendix 1**.

***Fig. 3**. Picture of the right bank of San Juan River, with an example of the interpretation of land use discussed in this report.*

Table 1

Types of land use identified in the interpretation of images before and after the construction of Route 1856

No.	Category	Description
1.	**Urbanized areas (Zonas urbanizadas)**	Areas with very few or no trees. Comprises surfaces covered by constructions such as houses or related buildings.
2.	**Crops (Cultivos)**	Areas dedicated to agricultural production, which are mainly distinguished by patterns and shapes that can be easily identified in the images and through field verification.
3.	**Pastures (Pastos)**	Highly disturbed areas, dominated by perennial grasses, non-prickly, with a height of less than 1 meter. This land is mainly for silvopastural use, and there maybe variations in its composition.
4.	**Pastures mixed with trees (Pastos mezclados con árboles)**	Corresponds to the previous category, except that there are trees spread out across a pasture.
5.	**Mountainous primary forest (Bosque primario de montaña)**	Primary forests are located in areas with moderate to high slopes, without significant or reduced human disturbance, and their structure and composition of flora show a state of climax.
6.	**Mountainous secondary forest (Bosque secundario de montaña)**	Are those forests located in areas with moderate to high slopes, which were once primary but have been disrupted by human activity. Their structure is similar to that of a primary forest in terms of strata, but they may differ in the diameter of their canopies, composition or homogeneity.
7.	**Plains primary forest (Bosque primario de planicie)**	Similar to that indicated for primary forests, but on a plain or slightly undulating surface.
8.	**Plains secondary forest (Bosque secundario de planicie)**	Similar to that indicated for secondary forests, but on a plain or slightly undulating surface.
9.	**Tree plantations (Plantaciones de árboles)**	Crop areas with presence of scattered trees.

NO.	CATEGORY	DESCRIPTION
10.	**Scrubland, degenerated forest** **(Charrales, bosque degenerado)**	Remnants of primary or secondary forests that were disturbed and logged, in which there is heterogeneous vegetation cover (less than 3 meters).
11.	**Temporarily flooded areas** **(Zonas temporalmente inundadas)**	Low areas close to river beds or water mirrors which in conditions of high precipitation may become flooded temporarily.
12.	**Raffia palms** **(Yolillales)**	Low areas, with humid soil, covered by raffia palms. They qualify as wetlands.
13.	**Lake wetlands** **(Humedales lacustrinos)**	Low areas with saturated soil and presence of water, with hydrophytic vegetation.
14.	**Bodies of water** **(Cuerpos de agua)**	Permanent or intermittent channels of water, and bodies of accumulated water.
15.	**Areas affected by the construction of Route 1856** **(Áreas afectadas por la Ruta 1956)**	Line of relief subject to earthworks for the construction of Route 1856. It includes cut slopes and fill slopes, road surface, shoulders and ditches, as well as temporarily loaned areas for aggregates for construction of the road.

2.2 COMPARATIVE MAPS

Figures 4-9 present the comparative maps of interpretation of land use for the one-kilometre wide strip analysed in this study. Component (a) of the figures shows the interpretation of land use before the construction of Route 1856, while component (b) shows after the construction of Route 1856.

In total, the portion from Marker 2 to Delta Costa Rica covered by this analysis includes six segments, namely:

Segment 1 (figures 4a & 4b): Marker 2 to Crucitas

Segment 2 (figures 5a & 5b): Crucitas to Mouth of San Carlos

Segment 3 (figures 6a & 6b): Mouth of San Carlos to Remolino Grande

Segment 4 (figures 7a & 7b): Remolino Grande to northwest of Trinidad

Segment 5 (figures 8a & 8b): Northwest of Trinidad to west of Tigra

Segment 6 (figures 9a & 9b): West of Tigra to Delta Costa Rica

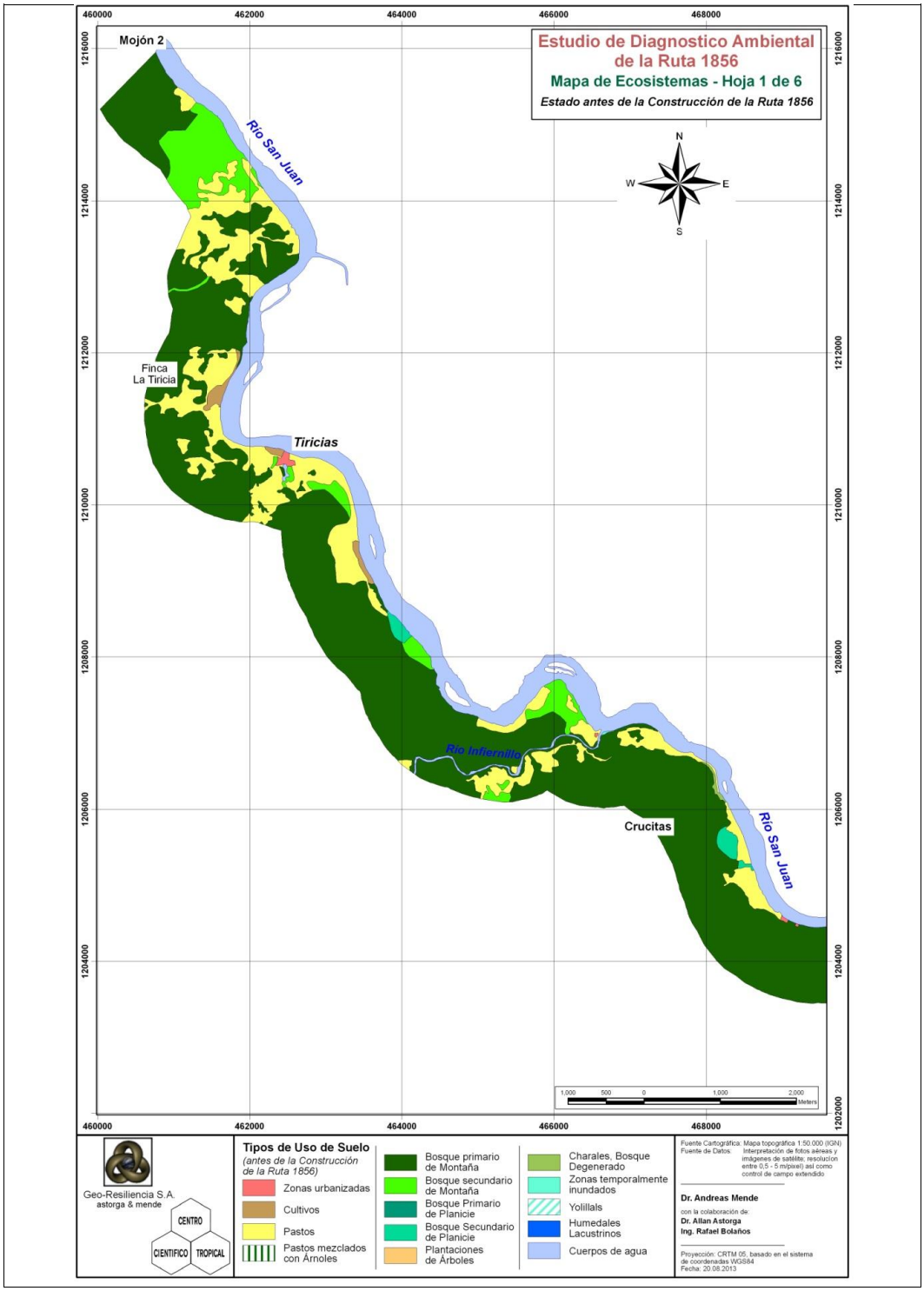


Fig. 4.a. *Segment 1, Marker 2 to Crucitas Sector before Route 1856*

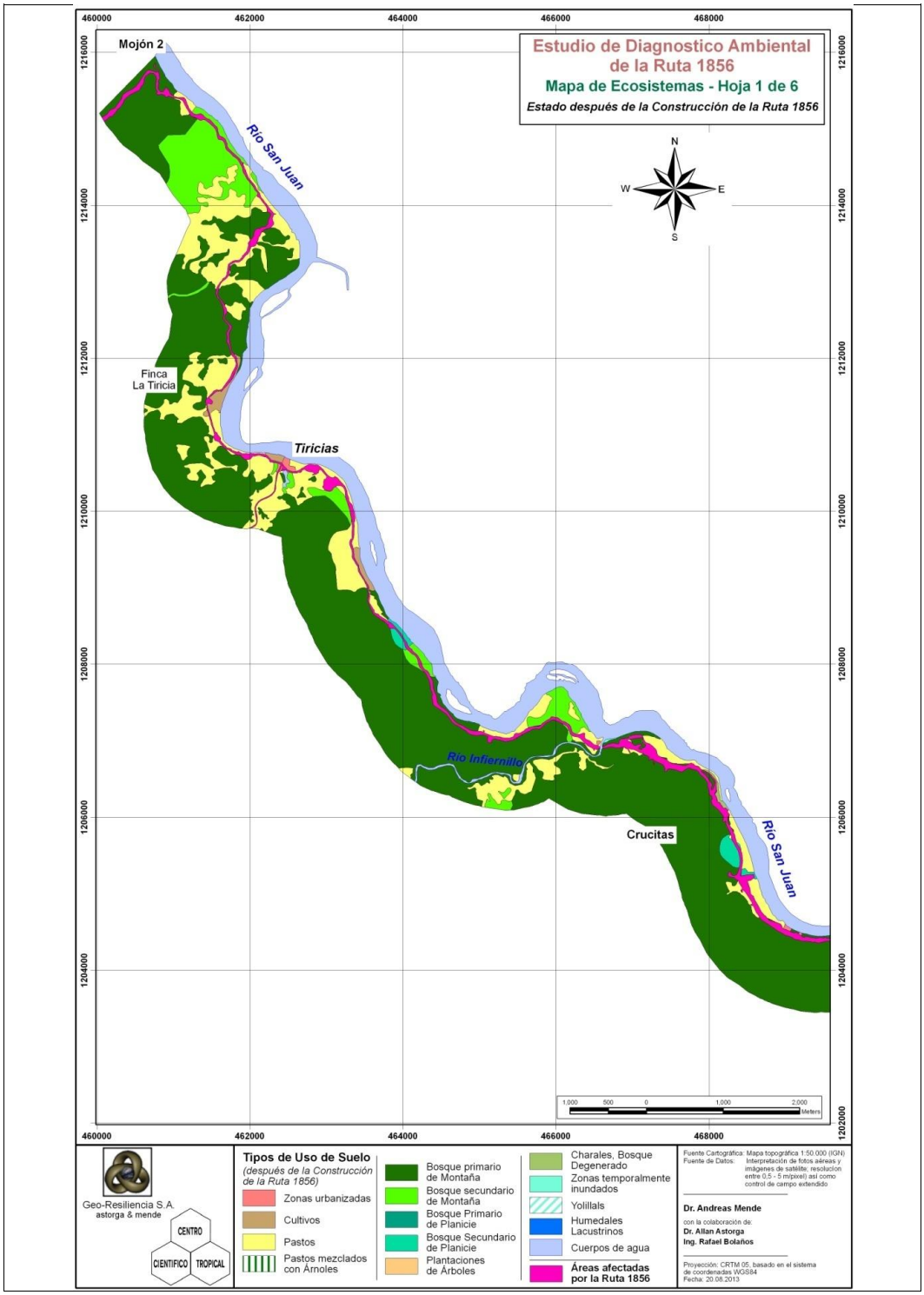


Fig. 4.b. *Segment 1, Marker 2 to Crucitas Sector after Route 1856*

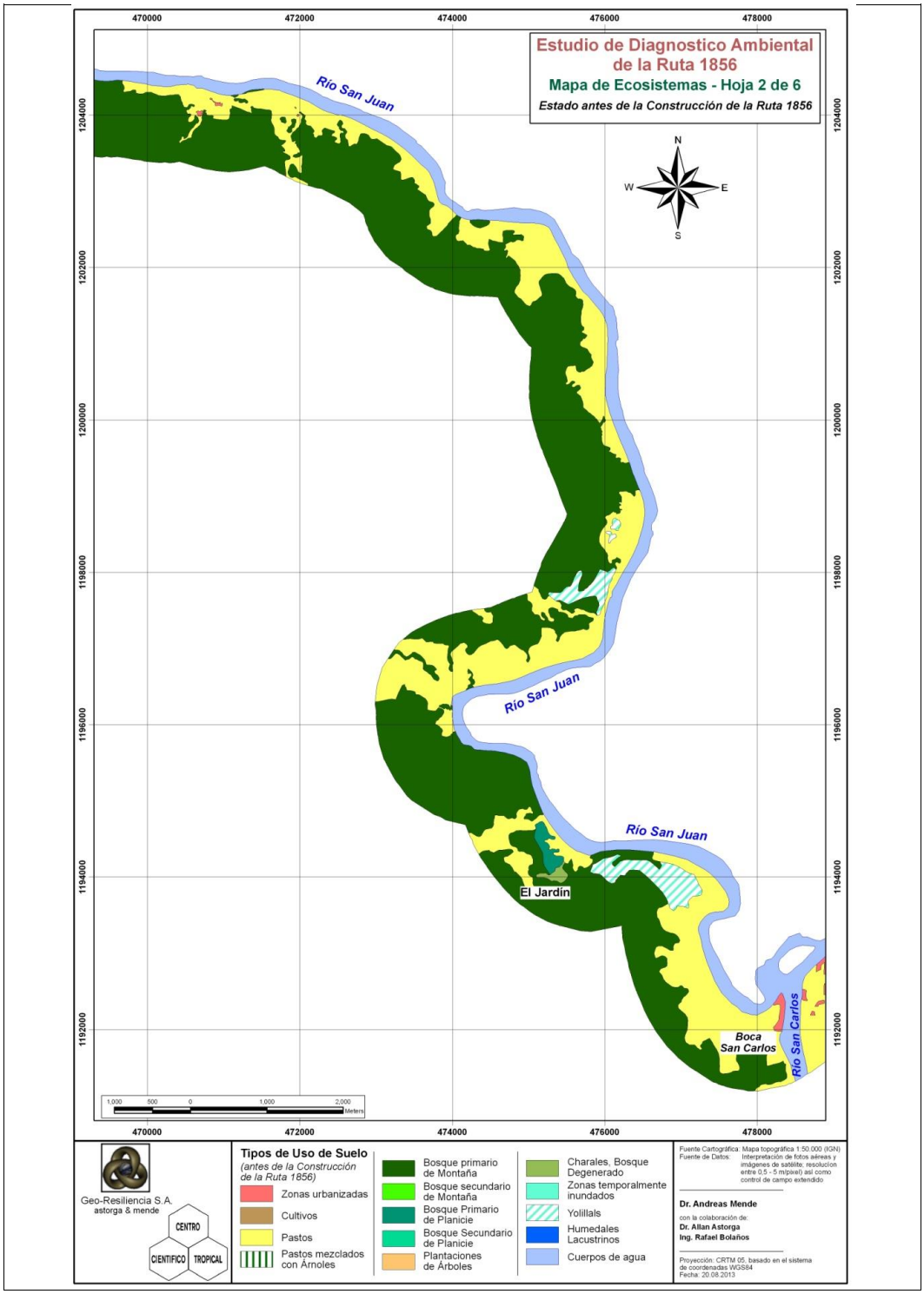


Fig. 5.a. *Segment 2, from Crucitas to Mouth of San Carlos before Route 1856*

Route 1856: analysis of the change in land use

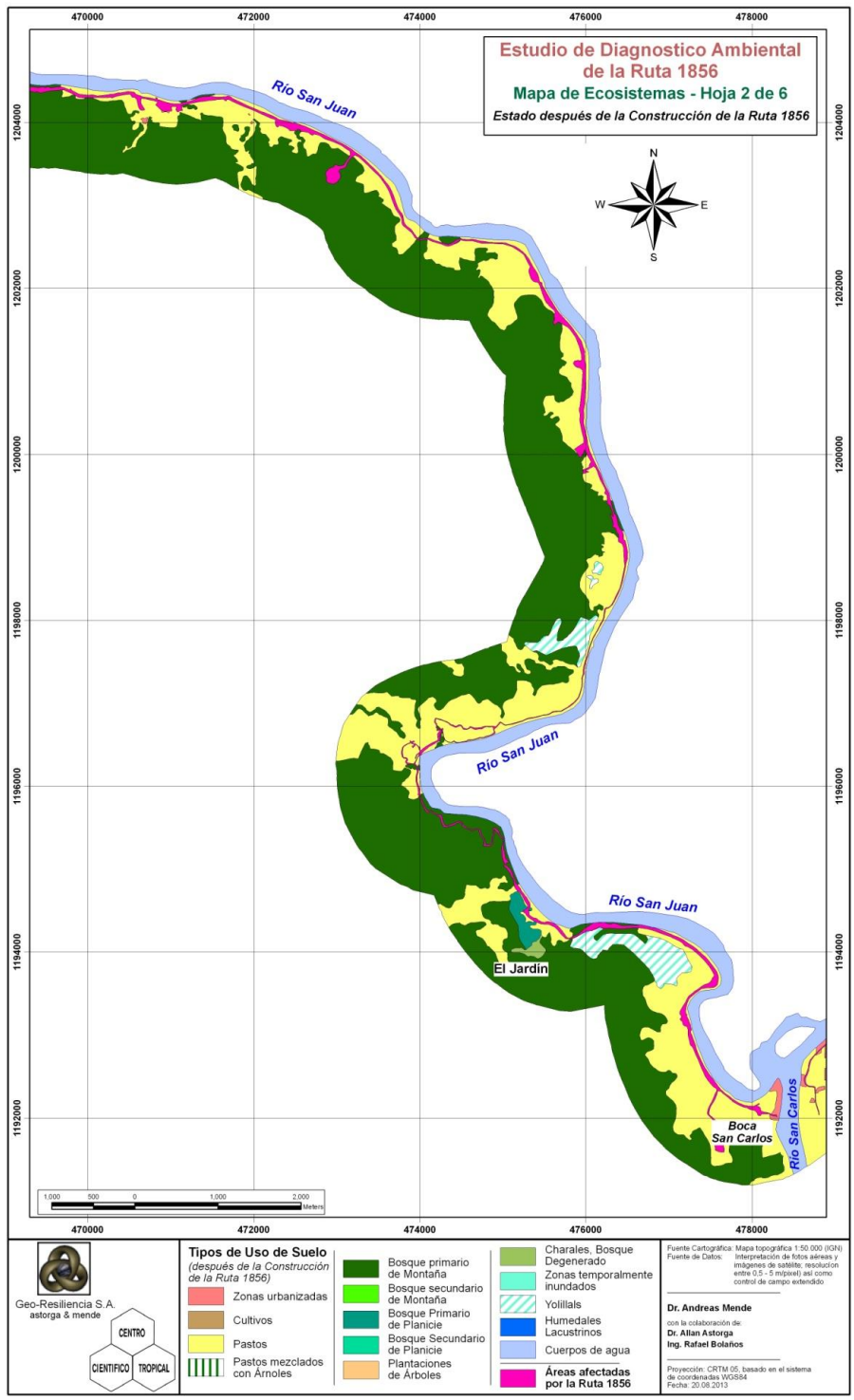


Fig. 5.b. *Segment 2, from Crucitas to Mouth of San Carlos after Route 1856*

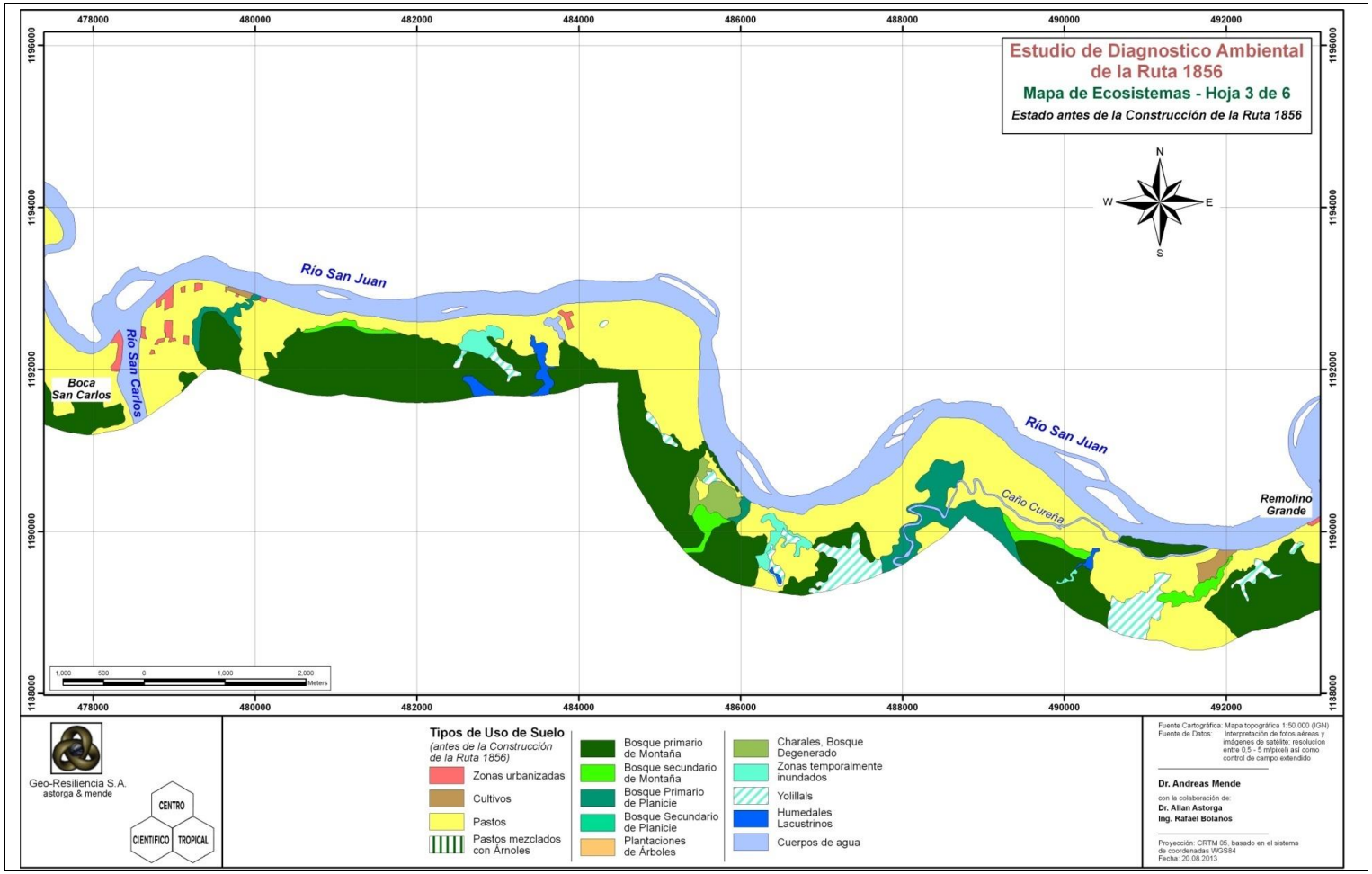


Fig. 6.a. *Segment 3, from the Mouth of San Carlos River to Remolino Grande, before Route 1856*

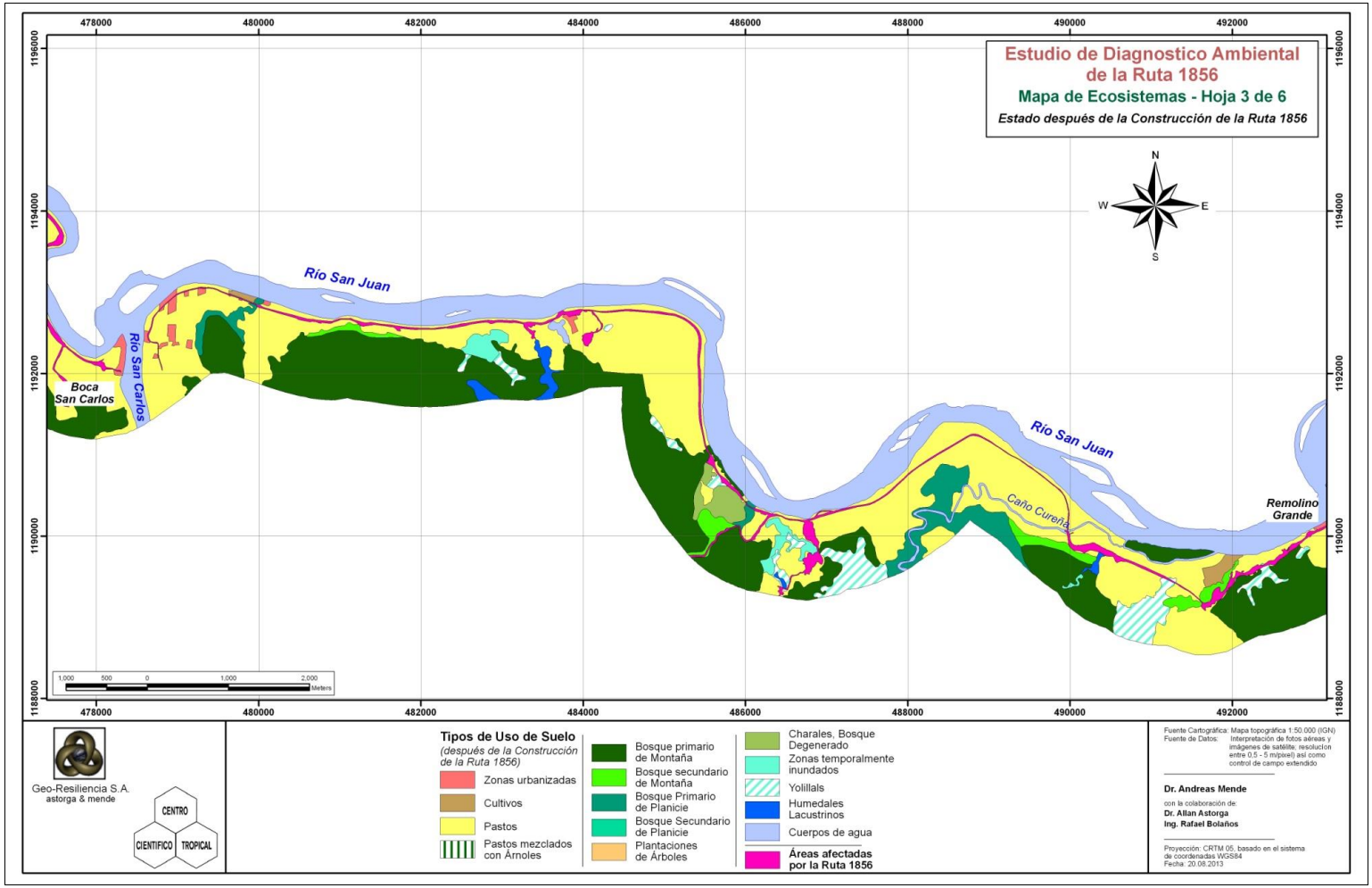


Fig. 6.b. *Segment 3, from the mouth of San Carlos River to Remolino Grande, after Route 1856*

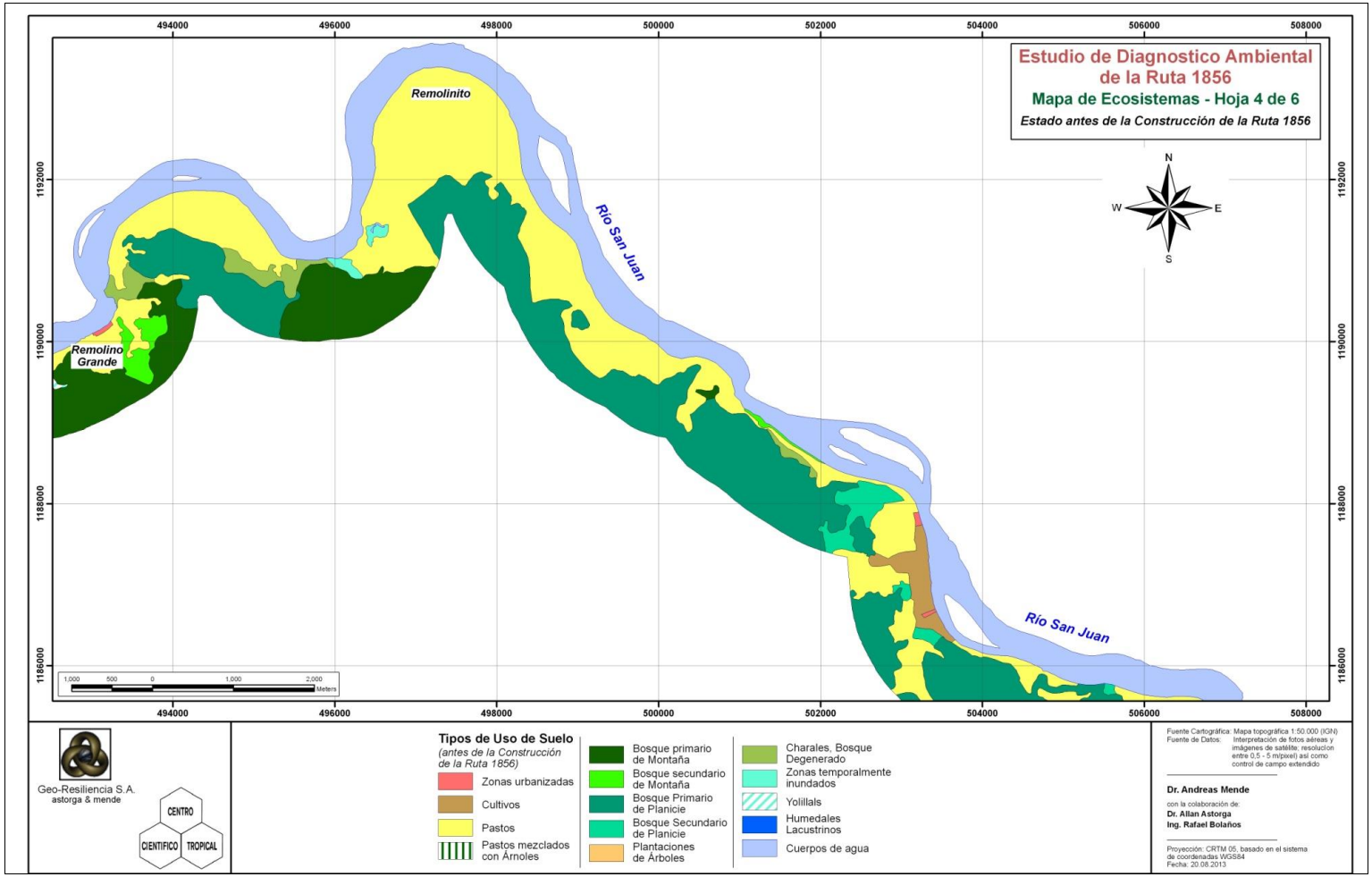


Fig. 7.a. *Segment 4, from Remolino Grande to northwest of Trinidad, before Route 1856*

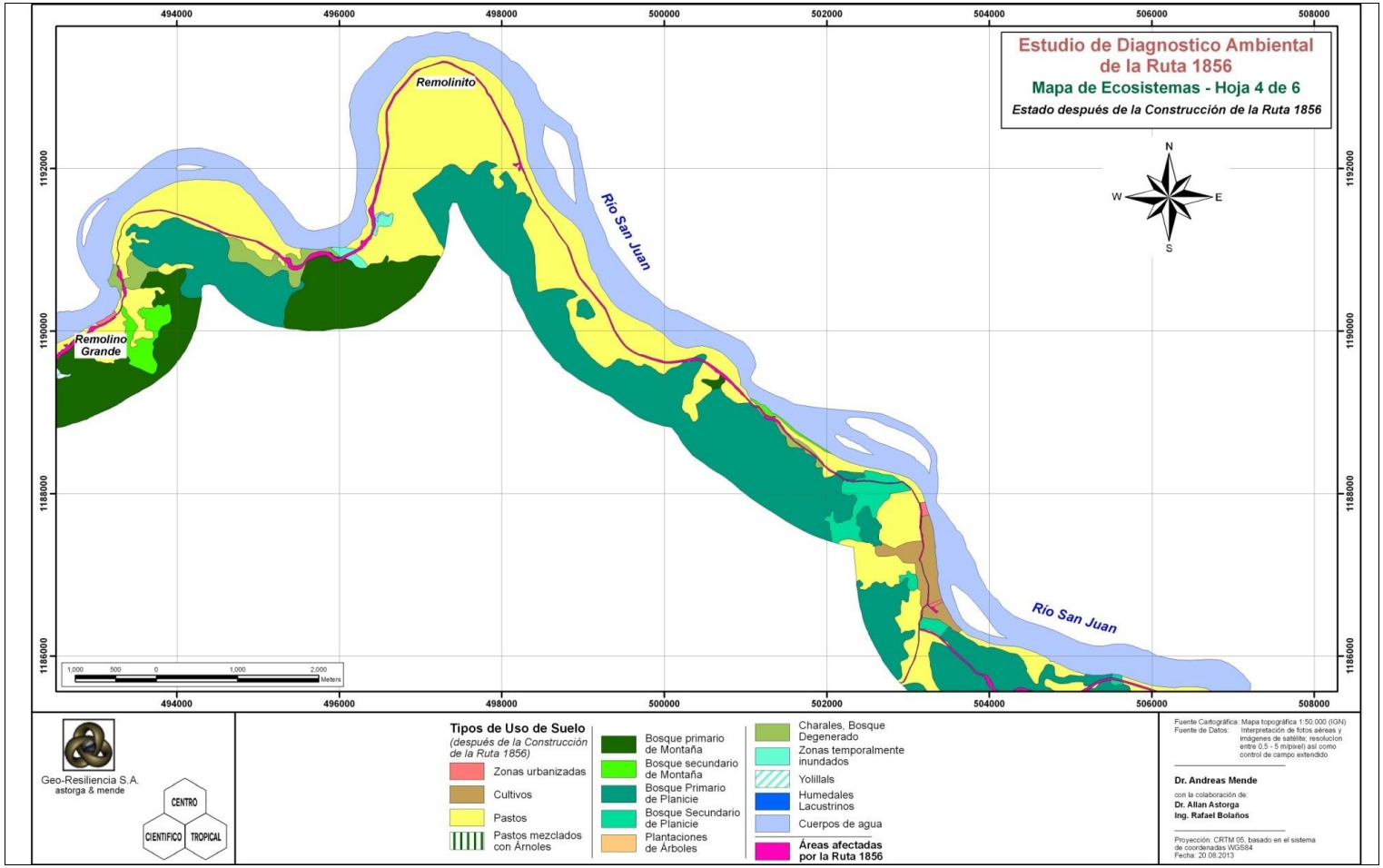


Fig. 7.b. *Segment 4, from Remolino Grande to northwest of Trinidad, after Route 1856*

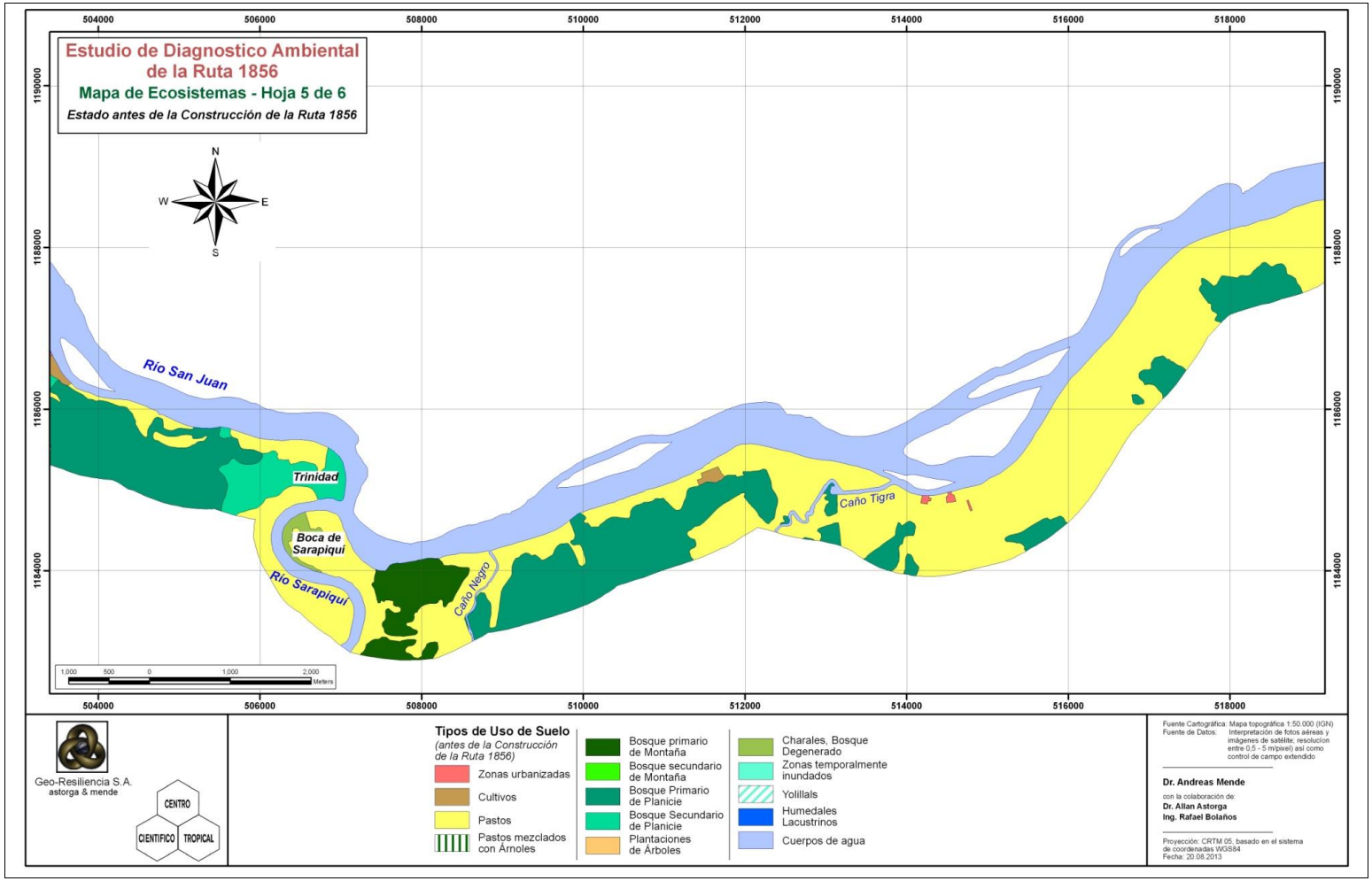


Fig. 8.a. *Segment 5, from northwest of Trinidad to west of Tigra, before Route 1856*

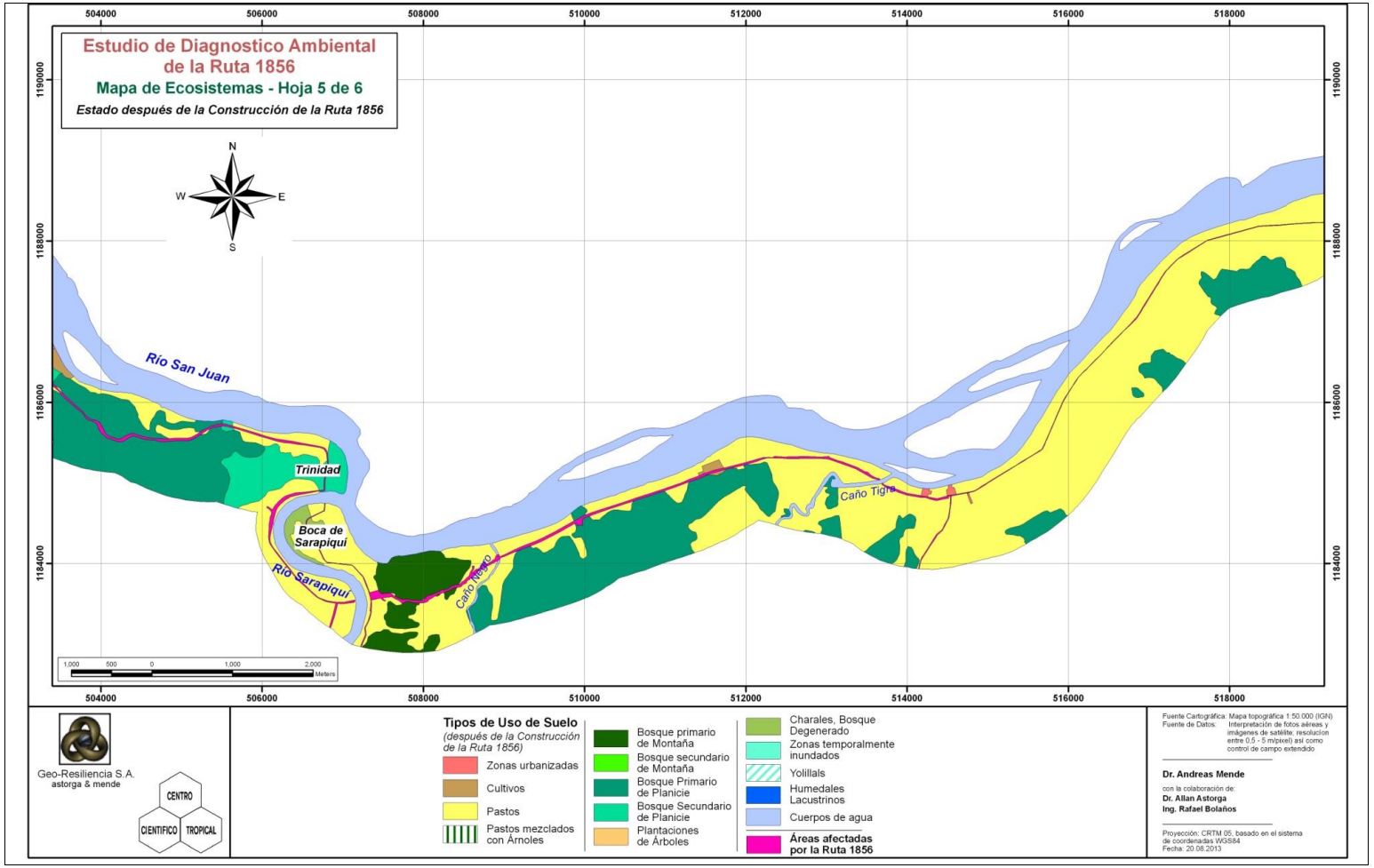


Fig. 8.b. *Segment 5, from northwest of Trinidad to west of Tigra, after Route 1856.*

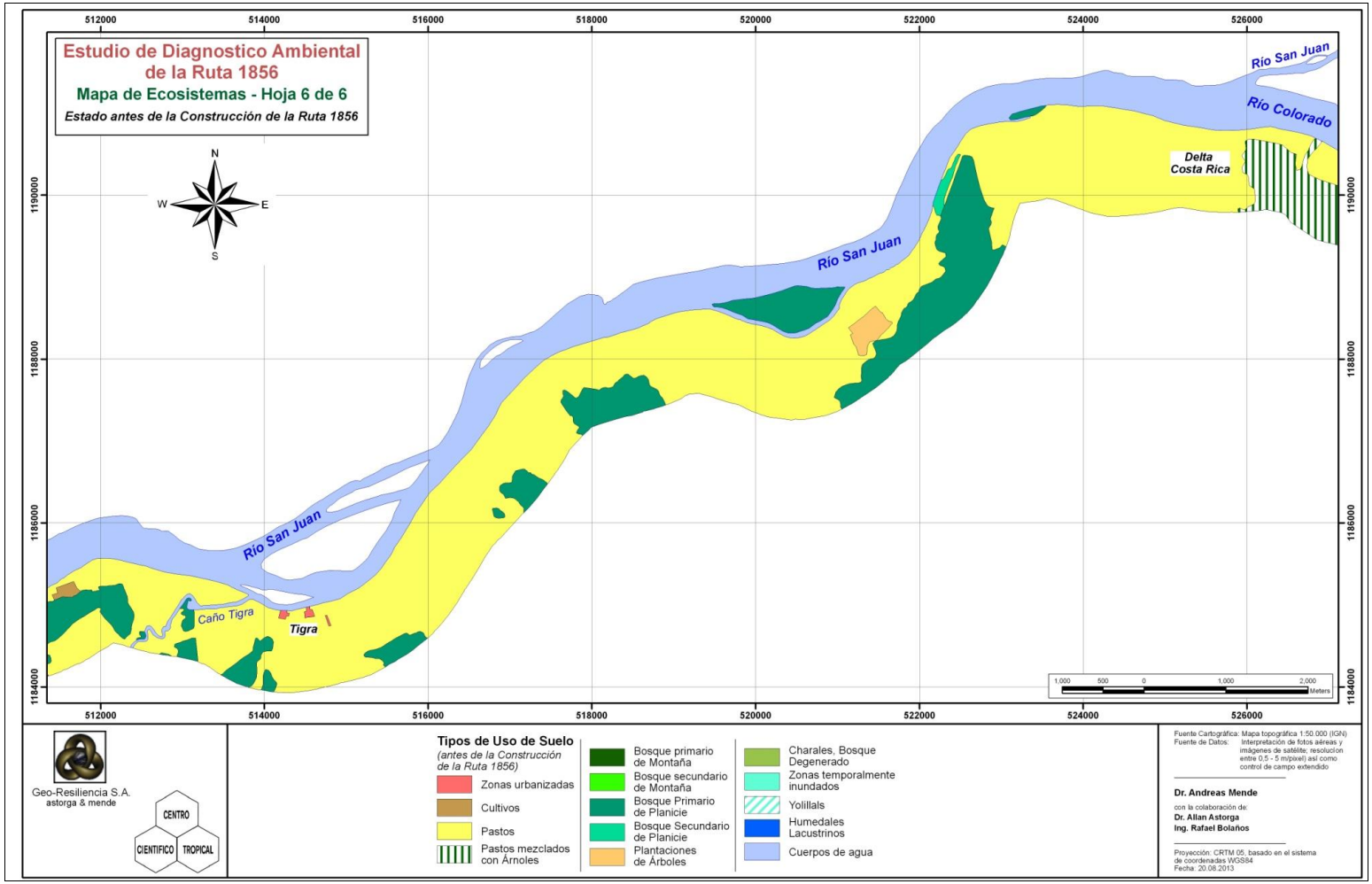


Fig. 9.a. *Segment 6, from west of Tigra to Delta Costa Rica, before Route 1856*

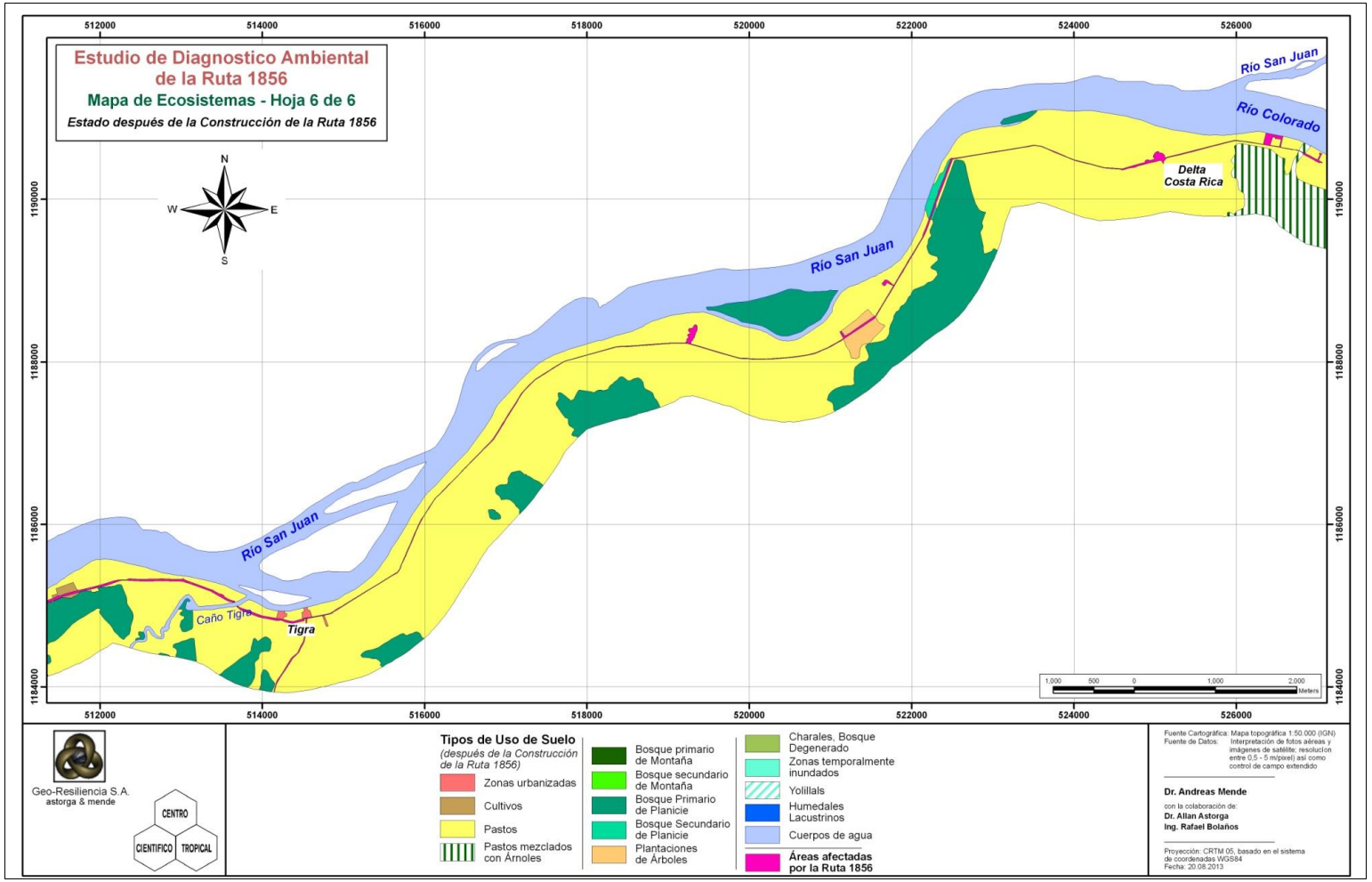


Fig. 9.b. *Segment 6, from west of Tigra to Delta Costa Rica, after Route 1856*

2.3 SUMMARY OF RESULTS

Table 2 presents the statistics, obtained using the Geographic Information System, of the different land uses before the construction of Route 1856 on the one-kilometre wide strip subject to this analysis, which represents a total of 10.475,2 hectares, i.e. 104.75 Km^2.

As we can see in Table 2, the most predominant land use in the area of study corresponds to the various types of forest, amounting to 5.469,6 hectares which represents 54.70% of the total. Pastures are in second place, with 4.497,9 hectares, or 44.98% of the total. Constructions (urbanized areas) represent coverage of 26.6 hectares, representing 0.3% of the total.

Table 2

Statistics of land use before the construction of Route 1856

Types of land use before Route 1856	Area (ha)	Area (km^2)	Area (%)
Urbanized areas	26.6	0.27	0.3
Annual / permanent crops	67.5	0.68	0.6
Pastures	4497.9	44.98	42.9
Pastures mixed with trees	103.1	1.03	1.0
Mountainous primary forest	3598.3	35.98	34.4
Mountainous secondary forest	211.4	2.11	2.0
Plains primary forest	1519.8	15.20	14.5
Plains secondary forest	140.1	1.40	1.3
Scrubland / Degenerated forest	89.5	0.89	0.9
Tree plantations	15.9	0.16	0.2
Raffia palms	150.4	1.50	1.4
Lake wetlands	18.0	0.18	0.2
Temporarily flooded areas	36.8	0.37	0.4
Sum	**10475.2**	**104.75**	**100.00**

Table 3, on the other hand, presents the statistics obtained using the Geographic Information System for the interpreted maps of land use after the construction of Route 1856. As we can see, the area directly affected by Route 1856 is 350 hectares, which represents 3.3% of the total area under analysis.

Table 4 presents the statistics of the effects of the construction of Route 1856 on the different land used identified in the area of study (see Table 2). As can be observed, the land use mainly affected by the construction of Route 1856 is pastures (253.5 hectares, representing 72.4% of the total). The forests (primary and secondary, mountainous and plains) affected by the construction of the Route represent 83.2 hectares, corresponding to 23.8% of the total area affected.

Table 3

Statistics of land use after the construction of Route 1856

Types of land use after Route 1856	Area (ha)	Area (km^2)	Area (%)
Urbanized areas	24.6	0.25	0.2
Annual / permanent crops	64.5	0.64	0.6
Pastures	4244.4	42.44	40.5
Pastures mixed with trees	103.0	1.03	1.0
Mountainous primary forest	3538.7	35.39	33.8
Mountainous secondary forest	202.0	2.02	1.9
Plains primary forest	1511.0	15.11	14.4
Plains secondary forest	134.7	1.35	1.3
Scrubland / Degenerated forest	84.5	0.84	0.8
Tree plantations	14.8	0.15	0.1
Raffia palms	149.7	1.50	1.4
Lake wetlands	17.9	0.18	0.2
Temporarily flooded areas	35.4	0.35	0.3
Areas affected by Route 1856	350	3.50	3.3
Sum	**10475.2**	**104.75**	**100.00**

Table 4

Net change in land use with the construction of Route 1856

Areas lost due to the construction of Route 1856	Area (ha)	Area (km^2)	Area (%)
Urbanized areas	2.0	0.020	0.6
Annual / permanent crops	3.0	0.030	0.9
Pastures	253.5	2.535	72.4
Pastures mixed with trees	0.1	0.001	0.0
Mountainous primary forest	59.6	0.596	17.0
Mountainous secondary forest	9.4	0.094	2.7
Plains primary forest	8.8	0.088	2.5
Plains secondary forest	5.5	0.055	1.6
Scrubland / Degenerated forest	5.0	0.050	1.4
Tree plantations	1.1	0.011	0.3
Raffia palms	0.7	0.007	0.2
Lake wetlands	0.1	0.001	0.0
Temporarily flooded areas	1.5	0.015	0.4
Sum	**350.2**	**3.50**	**100.00**

3. Conclusions

1. The area occupied by Route 1856 between Marker 2 and Delta Costa Rica is 350.2 hectares.

2. This represents 3.3% of the 10 447.2 hectare study area (which is a one kilometre wide corridor extending between Marker 2 and Delta Costa Rica).

3. The area of pasture which is now used for Route 1856 is 253.5 hectares, which constitutes 72.4% of the area which is now used for the Road.

4. As the pasture land had already been cleared of natural vegetation and developed for agriculture prior to construction of Route 1856, the impacts of the Road on the environment, ecology, soil erosion and sediment production along nearly three quarters of its length are likely to range between low and imperceptible.

5. The overall area of forest lost to Route 1856 is 83.2 hectares, representing 23.8 % of the area now used for the Road. However, only 68.4 hectares of area now used for the Road was mapped as primary forest prior to construction and most of this (59.56 hectares, i.e. 87%) is located upstream of Boca San Carlos.

6. In total, the area of forest now used for Route 1856 constitutes only 0.014 % of the 5 869.6 hectares of forest found within the study corridor.

7. The relatively small area of forest now used for Route 1856 reflects the fact that its route was planned to avoid primary forest as much as possible and examination of the land use maps in Figures 4 to 9 illustrates the degree to which the Road skirts around rather than passing through forested areas, particularly downstream of Boca San Carlos.

5. Based on the foregoing, we conclude that the land use impacts of Route 1856 are mainly confined to pastures and that, although a total of 83.2 hectares of forest are now used for the Road, the route selected minimised the amount of primary forest that had to be cut.

4. References

Executive Decree No. 32967 - (Ministry of the Environment and Energy) **MINAE: Manual of Technical Instruments for Environmental Impact Assessments (EIA Manual), Part III-. TECHNICAL PROCEDURE TO INTRODUCE THE ENVIRONMENTAL VARIABLE IN REGULATORY PLANS OR OTHER PLANS FOR LAND USE.** Official Gazette, May 6, 2006).

ANNEX 4

Costa Rican Institute of Electricity (ICE), SBU Projects and Associated Services, Centre for Basic Engineering Studies, Department of Hydrology

Report on Hydrology and Sediments for the Costa Rican River Basins draining to the San Juan River

August 2013

COSTA RICAN INSTITUTE OF ELECTRICITY (ICE)
SBU PROJECTS AND ASSOCIATED SERVICES
CENTRE FOR BASIC ENGINEERING STUDIES
DEPARTMENT OF HYDROLOGY

REPORT ON HYDROLOGY AND SEDIMENTS FOR THE COSTA RICAN RIVER BASINS DRAINING TO THE SAN JUAN RIVER

August 2013
San José, Costa Rica

Prepared by:

Federico Gómez Delgado
Juan José Leitón Montero
Carlos Aguilar Cabrera

With the collaboration of:

Sadí Laporte Molina
José Alberto Zúñiga Mora
Marcelo Avendaño Castro and the URM Unit
José Francisco Fernández Araya and the ULQ Unit
Berny Fallas López and the UPA Unit

Contents

1. Introduction 1
2. Hydrology and sediment measurements in the San Juan - Colorado river system 3
2.1. Study area and gauging stations 3
2.2. Mean monthly discharge for ICE's hydrological stations 4
2.3. Suspended sediment load from Costa Rican basins draining to the San Juan River 6
2.3.1 Suspended sediment rating curves for the stations 01-03 La Trinidad and 11-04 Delta Colorado 7
2.3.2 Seasonal behavior of the suspended sediment concentrations at Delta Colorado station (11-04) 8
2.3.3 Mean annual suspended sediment load at La Trinidad (01-03) and Delta Colorado (11-04) gauging stations 9
2.4. Bed-load sediment from Costa Rican basins draining to the San Juan River 10
3. Discharge balance in the San Juan - Colorado river system 14
4. Hydrological regime in the tributary basins draining from Costa Rica to the San Juan River, before and after the construction of Route 1856 16
4.1. Impermeable areas in the basins draining to the RSJ 17
4.2. Hydrological regime of all the rivers and streams flowing to the San Juan River from Costa Rican basins: Evaluation of Route 1856 18
5. Distributed erosion and sediment yield in the San Juan - Colorado river system 21
6. Sediment balance in the San Juan - Colorado river system, before and after construction of Route 1856 26
6.1. Total annual sediment load after construction of Route 1856 26
6.2. Estimation of the sediment load produced by Route 1856 28
6.3. Sediment balance diagrams before and after construction of Route 1856 32
6.4. Silting process in the lower San Juan River 34
7. Conclusions 36
REFERENCES 38
APPENDIX A Suspended sediment rating curves Mean monthly suspended sediment load Mean annual suspended sediment load 40
APPENDIX B Monthly discharge measurements by Doppler device at Delta Colorado (11-04) gauging station 65
APPENDIX C Daily discharge at Delta Colorado (11-04) gauging station for the period December 2010 - July 2013 66

APPENDIX D Suspended sediment (SS) samples taken at La Trinidad (01-03, Jan 1974 - Mar 1976) and Delta Colorado (11-04, Dec 2010 - Jun 2013) gauging stations 67

APPENDIX E Grain size distribution for bed-load samples, taken in a monthly basis within the period December 2010 - June 2013 at the mouths of the San Carlos and Sarapiquí Rivers, and at Delta Colorado station (11-04) 69

APPENDIX F Distributions of both bed-load median grain size and percentage of sand, sampled within the period December 2010 - June 2013 at Delta Colorado station (11-04) 70

APPENDIX G Estimation of the annual bed-load sediment according to the Einstein method, for the period 2010-2013 in the Lower San Juan and Colorado Rivers 71

APPENDIX H H.1 Flow diagram and description of the CALSITE model H.2 Input and output maps produced for the determination of the potential erosion and sediment yield in both Costa Rican and Nicaraguan drainage basins 72

APPENDIX I Disaggregated diagrams, by sediment load component, of the sediment balance in the San Juan - Colorado River system, before and after Route 1856 construction 80

List of Tables

Table 1. Properties of the hydrological gauging stations located in the San Juan / Colorado Rivers and in the hydrological-sediment stations located within the Costa Rican basins draining to the San Juan River 4
Table 2. Properties of the sediment gauging stations in the Costa Rican basins draining to San Juan River 7
Table 3. Discharge from Costa Rican river basins draining to the San Juan - Colorado River (ICE, 2010) 14
Table 4. Discharge values from Costa Rican and Nicaraguan sides, draining to San Juan - Colorado River 14
Table 5. Maximum increase in the impermeable area of the basins draining to SJR from C. Rica 17
Table 6. Discharge regime for the microbasins draining to the San Juan River, modelled using HEC-HMS from 1976 to 2013, or conditions with and without the presence of Route 1856 18
Table 7. Discharge regime for all the basins (micro and macro) draining to the San Juan River. Times series generated from 1971 to 2006 for pre- and post-Route 1856 conditions 20
Table 8. Estimate sediment yields for Costa Rican basins 22
Table 9. Estimate sediment yields for Nicaraguan basins 24
Table 10. Total annual sediment load (including suspended and bed loads) produced by the Lake Nicaragua and the basin system draining to the San Juan River 27
Table 11. Corrected annual loads for Lake Nicaragua and the basin system draining to San Juan River 28
Table 12. Potential sediment increments to the San Juan River sediment load due to construction of Route 1856 (basin discretized) 30
Table 13. Sediment yield increments to the San Juan River sediment load due to construction of Route 1856 (basin discretized) 31

List of Figures

Figure 1. Hydrological/sediment stations located in Costa Rican basins draining to the San Juan River and in the main stream of the San Juan River. 3
Figure 2. Mean monthly discharge recorded in fourteen gauging stations property of ICE, located in three main river basins and at San Juan and Colorado rivers.... 6
Figure 3. Suspended sediment (SS) rating curves for La Trinidad (01-03) and Delta Colorado (11-04) gauging stations 8
Figure 4. Suspended sediment (SS) rating curves for Delta Colorado (11-04) gauging stations, grouped by climatic season 9
Figure 5. Mean annual suspended sediment load at La Trinidad station (01-03), which is located directly in the San Juan River; compared to the weighted estimation of the respective load in the San Juan River, obtained from the measurements at Delta Colorado station (11-04), which is located in the Colorado River just after the bifurcation of these two rivers 10
Figure 6. Frequency distribution of the sand percentage for all bed-load samples. 11
Figure 7. Bed-load sediment rating curve for particles larger than 0.063 mm at the Delta Colorado (11-04) station. 12
Figure 8. Streamflow and bed-load sediment load regimes: Station 11-04 Delta Colorado (Dec 2010 - Jul 2013). 12
Figure 9. Bed-load sediment rating curve for particles larger than 0.063 mm. Lower San Juan River. 13
Figure 10. Streamflow and bed-load sediment load regimes: Lower San Juan River (Dec 2010 - Jul 2013). 13
Figure 11. Discharge balance in the San Juan - Colorado River system. 15
Figure 12. Tributary basins draining to the San Juan River. 16
Figure 13. Discharge regime for the microbasins draining to the San Juan River, modelled using HEC-HMS from 1976 to 2013, for conditions with and without the presence of Route 1856. 19
Figure 14. Discharge regime for all the basins (micro and macro) draining to the San Juan River. Times series generated from 1971 to 2006 for pre- and post-Route 1856 conditions. 20
Figure 15. Specific sediment yields for Costa Rican basins draining to the San Juan River. 22
Figure 16. Total sediment yields for Costa Rican basins draining to the San Juan River. 23
Figure 17. Delivery ratios for Costa Rican basins draining to the San Juan River. 23
Figure 18. Specific sediment yields for Nicaraguan basins draining to the San Juan River. 24
Figure 19. Total sediment yields for Nicaraguan basins draining to the San Juan River. 25
Figure 20. Delivery ratios for Nicaraguan basins draining to the San Juan River. 25

Figure 21. Potential erosion from the road bed and cut and fill slopes due to construction of Route 1856 (displayed by tributary basin, with the length of the road located in each basin indicated for context)..... 30
Figure 22. Sediment yields to the San Juan River due to construction of Route 1856 (displayed by tributary basin, with the length of road located in each basin indicated for context)..... 31
Figure 23. Average annual sediment balance prior to construction of Route 1856. 32
Figure 24. Average annual sediment balance post construction of Route 1856. ica. 33
Figure 25. Increases in average annual sediment loads input to the San Juan – Colorado River system due to construction of Route 1856 34

1. INTRODUCTION

This report has been prepared at the request of the Honourable Laura Chinchilla Miranda, President of the Republic of Costa Rica, and the Honourable José Enrique Castillo Barrantes, Minister of Foreign Affairs of the Republic of Costa Rica. It aims to provide the necessary technical information required by the Government of Costa Rica to address the claim brought against it by the Government of Nicaragua before the International Court of Justice (ICJ) in The Hague, Netherlands.

The three primary authors of this report are as follows:

Federico Gómez Delgado is a hydrologist graduated as Civil Engineer from the University of Costa Rica, where he also received the degree of *Magister Scientiae* in Statistics. Later he obtained his Ph.D. degree in Hydrology at the SIBAGHE Doctoral School of the University of Montpellier, France. In 2002 he began working in the Department of Hydrology of the Costa Rican Institute of Electricity (ICE*, by its Spanish acronym*), and later in the Planning Unit for Integrated Expansion of the Electrical System. He was subsequently appointed as Coordinator of the Department of Hydrology, and later on as Director of ICE's Centre for Basic Engineering Studies. Among other posts, Mr. Gómez chaired the National Committee for Hydrology and Meteorology, was a member of the National Meteorological Council, served as Hydrological Advisor to the Permanent Representative of Costa Rica with WMO, and also as served as President of the Costa Rican National Committee for UNESCO-IHP.

Juan José Leitón Montero is a Civil Engineer currently working at the Costa Rican Institute of Electricity (ICE). He has worked as a hydrology-hydraulic engineering assistant for civil and hydroelectric projects since 2010, and since 2012 works as investigator at the Hydrology Department of the Centre for Basic Engineering Studies of ICE. He graduated with honors by the University of Costa Rica (2012) and currently is part of the Graduate Program of Mathematics with emphasis on Applied Math at the very same university.

Carlos Andrés Aguilar Cabrera is a senior year Civil Engineering and Theoretical Physics student at the University of Costa Rica. He worked as assistant for the Department of Hydrology at ICE, and also supported the field studies as assistant for CIEDES at the University of Costa Rica. He has hydraulic engineering, hydrology and soil laboratory experience, as part of the standard Civil Engineering Programme; the programme is deemed as substantially equivalent by the Canadian Engineering Accreditation Board.

The Costa Rican Institute of Electricity (ICE) is a national institute dedicated to the identification, design, development and operation of electricity and telecommunications projects, required to provide these kinds of services to the Costa

Rican society. Since the founding of the Institute in 1949, the Electrical Division has specialized in conducting hydrological and sedimentological measurements and studies based on world-class scientific and engineering standards, which have been applied over time in a large number of basins and microbasins of the country.

In two of the major Costa Rican basins draining to the San Juan River, the San Carlos and Sarapiquí river basins, ICE has built several hydroelectric facilities of strategic importance for the country. The most relevant hydro-sedimentological information collected by ICE over recent decades is provided in this report, along with the data recorded for nearly three years in a gauging station deployed at Delta Costa Rica, and the corresponding descriptive and inferential analysis of all these data. In addition, in accordance with ICE's knowledge and understanding of the hydro-sedimentological processes that characterize the river basins of this region, the report includes a chapter establishing the annual discharge (streamflow) balance in the San Juan - Colorado River system, based on direct measurements performed by both ICE and the Nicaraguan Institute of Territorial Studies (INETER). An analysis of the hydrological regime of Costa Rican basins draining to the San Juan River is also presented, along with a particular hydrological assessment of Route 1856 within this framework. The distributed erosion and sediment transport processes are modelled using a high-level scientific methodology, which benefits from the sedimentological observations carried out over decades in the Costa Rican basins to calibrate the model, and then estimations of sediment yield for the river basins draining to the San Juan River are produced. Finally, a sediment balance is presented for the entire basin system, including a specific analysis of Route 1856.

Throughout all the chapters of this report it becomes clear that the San Juan River basin is a large system in the local context, which is being governed by large-scale natural processes at both time and space scales. The natural variability of these processes implies that, according to scientifically sound methodologies, they can only be quantified within certain bounds of uncertainty. Different sections of this report demonstrate that the hydrological and sedimentological effects of the construction of Route 1856 are not only minuscule in comparison with the order of magnitude of the natural processes that characterize the San Juan River system, but that they even fall well within the margin of error of the quantification of such natural processes, meaning that they are undetectable and that the Road's impacts on water flows, sediment loads, sediment concentrations, sedimentation, and the morphology of the San Juan River are not just insignificant, they are, in practice, indiscernible.

2. HYDROLOGY AND SEDIMENT MEASUREMENTS IN THE SAN JUAN - COLORADO RIVER SYSTEM

This chapter describes the different hydrological and sediment measurements that have been carried out by ICE in the different river basins draining to the San Juan - Colorado River Basin System.

2.1. Study area and gauging stations

Over time, ICE has installed twelve discharge and sediment flow gauging stations in three out of seven of the Costa Rican basins draining to the San Juan River: Frío River basin, San Carlos River basin and Sarapiquí River basin. In addition, three discharge stations have been deployed directly in the San Juan River, while by the end of 2010 ICE installed a discharge/sediment gauging station in the Colorado River, just downstream of the bifurcation of the San Juan River at Delta Costa Rica. The location of all these sixteen stations, as well as the delineation of the seven major Costa Rican basins draining to the San Juan River, are indicated on Figure 1.

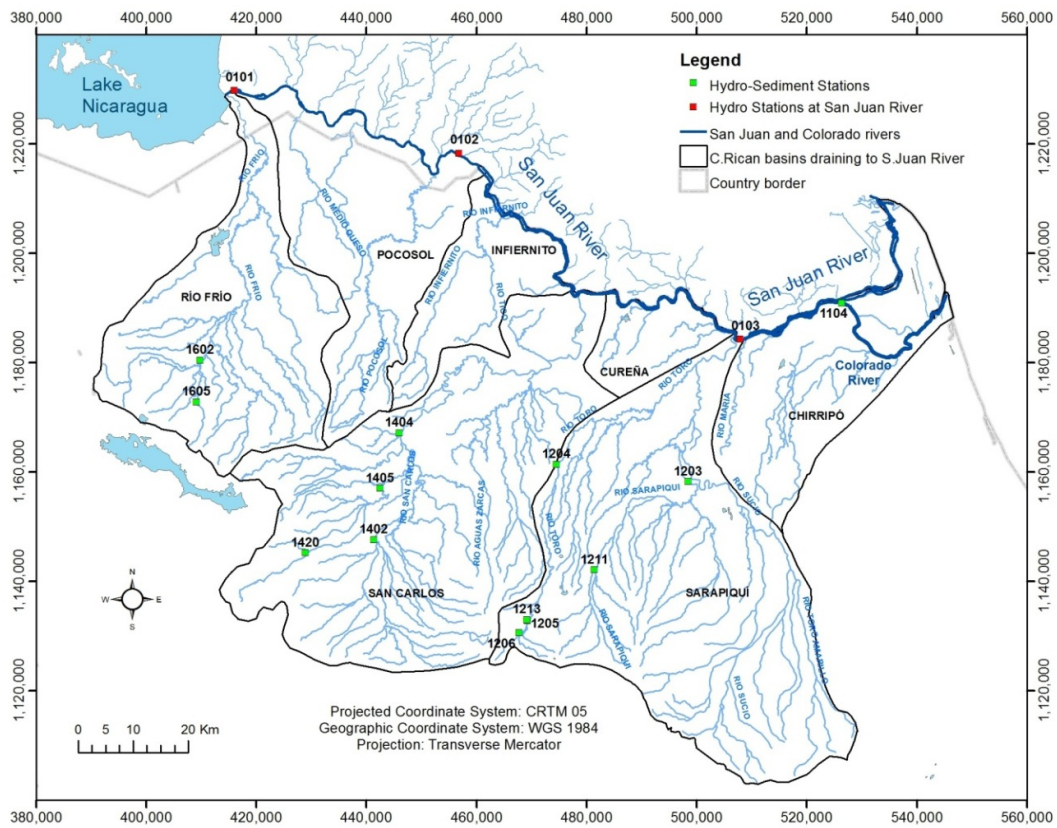


Figure 1. Hydrological/sediment stations located in Costa Rican basins draining to the San Juan River and in the main stream of the San Juan River.

In addition, for each of these stations, relevant information such as the tributary drainage area, the time period during which the measurements were carried out and the mean discharge recorded in the river over the corresponding period, among others, are presented in Table 1.

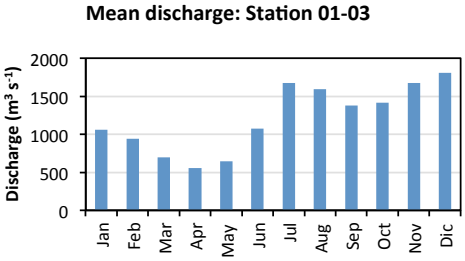
Table 1. Properties of the hydrological gauging stations located in the San Juan / Colorado Rivers and in the hydrological-sediment stations located within the Costa Rican basins draining to the San Juan River

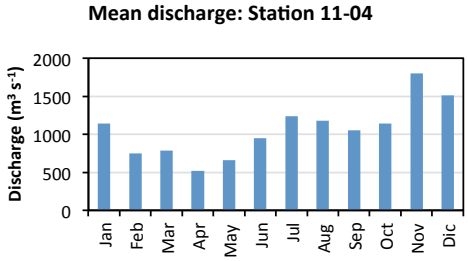
Station code	Station Name	River	Basin	DA (km^2)	Record period	Q ($m^3 s^{-1}$)	Active to date
01-01[a]	San Carlos	San Juan	San Juan	30 306[c]	1965-1986[c]	297[c]	No
01-02[a]	El Castillo	San Juan	San Juan	32 819[d]	1971-1981 1997-1998[b]	422[b]	No
01-03	La Trinidad	San Juan	San Juan	38 730[e]	1973-1976[e]	1123	No
11-04	Delta Colorado	Colorado	San Juan	-	2010-2013	1026	Yes
12-03	Puerto Viejo	Sarapiquí	Sarapiquí	845	1968-1999	113	No
12-04	Veracruz	Toro	Sarapiquí	191	1971-2013	26	Yes
12-05	Bajos del Toro	Toro	Sarapiquí	73	1985-1996	6,7	No
12-06	Toro	Toro	Sarapiquí	41	1993-2013	4,4	Yes
12-11	San Miguel	Volcán	Sarapiquí	59	1998-2002 2010-2013	11	Yes
12-13	Río Segundo	Segundo	Sarapiquí	17	1999-2013	2,7	Yes
14-02	Jabillos	San Carlos	San Carlos	552	1963-2013	51	Yes
14-04	Terrón Colorado	San Carlos	San Carlos	1556	1968-2008	166	No
14-05	Peñas Blancas	Peñas Blancas	San Carlos	293	1968-2013	35[f]	Yes
14-20	Pocosol	Peñas Blancas	San Carlos	124	1980-2013	19	Yes
16-02	Guatuso	Frío	Frío	253	1969-2013	28	Yes
16-05	Santa Lucía	Venado	Frío	34	1982-2013	3,9	Yes

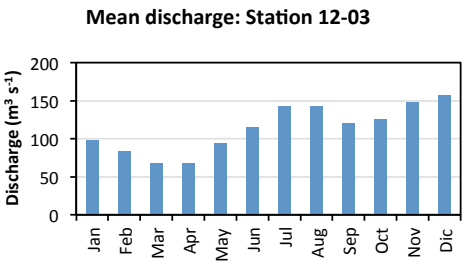
Note: DA = drainage area; Q = mean annual discharge.
[a]Stations installed, coded and operated by the INETER of Nicaragua. [b]INETER (2001). [c]INETER (2002). [d]INETER (2006). [e]ICE (1973). [f]Since 2002 the discharges are regulated by the Peñas Blancas hydropower plant.

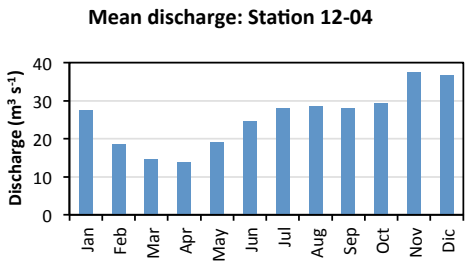
2.2. Mean monthly discharge for ICE's hydrological stations

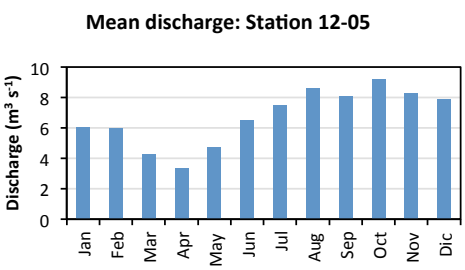
For the periods indicated in Table 1, the mean monthly discharge in the river at each station was calculated and represented in Fig. 2. In particular, a special survey was carried out at the Delta Colorado station, where thirty discharge samples have been taken between December 2010 and June 2013.

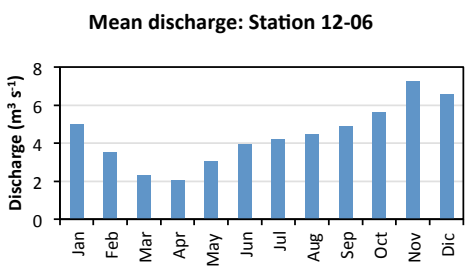

Mean discharge: Station 01-03
Discharge (m³ s⁻¹)
2000
1500
1000
500
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic

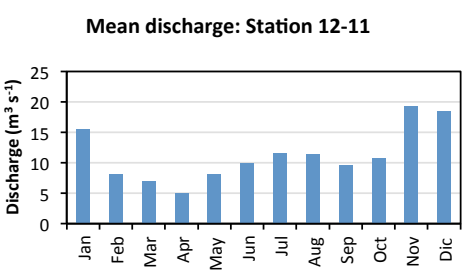

Mean discharge: Station 11-04
Discharge (m³ s⁻¹)
2000
1500
1000
500
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic

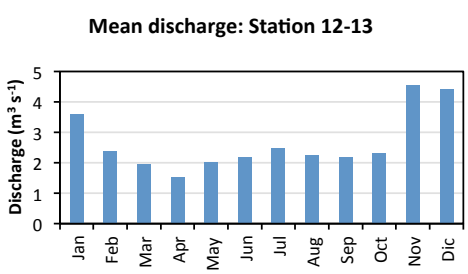

Mean discharge: Station 12-03
Discharge (m³ s⁻¹)
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic

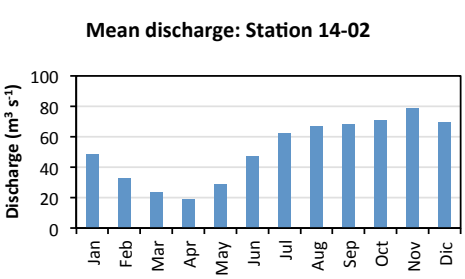

Mean discharge: Station 12-04
Discharge (m³ s⁻¹)
40
30
20
10
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic

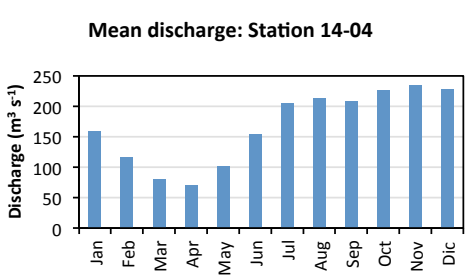

Mean discharge: Station 12-05
Discharge (m³ s⁻¹)
10
8
6
4
2
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic


Mean discharge: Station 12-06
Discharge (m³ s⁻¹)
8
6
4
2
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic


Mean discharge: Station 12-11
Discharge (m³ s⁻¹)
25
20
15
10
5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic


Mean discharge: Station 12-13
Discharge (m³ s⁻¹)
5
4
3
2
1
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic


Mean discharge: Station 14-02
Discharge (m³ s⁻¹)
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic


Mean discharge: Station 14-04
Discharge (m³ s⁻¹)
250
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dic

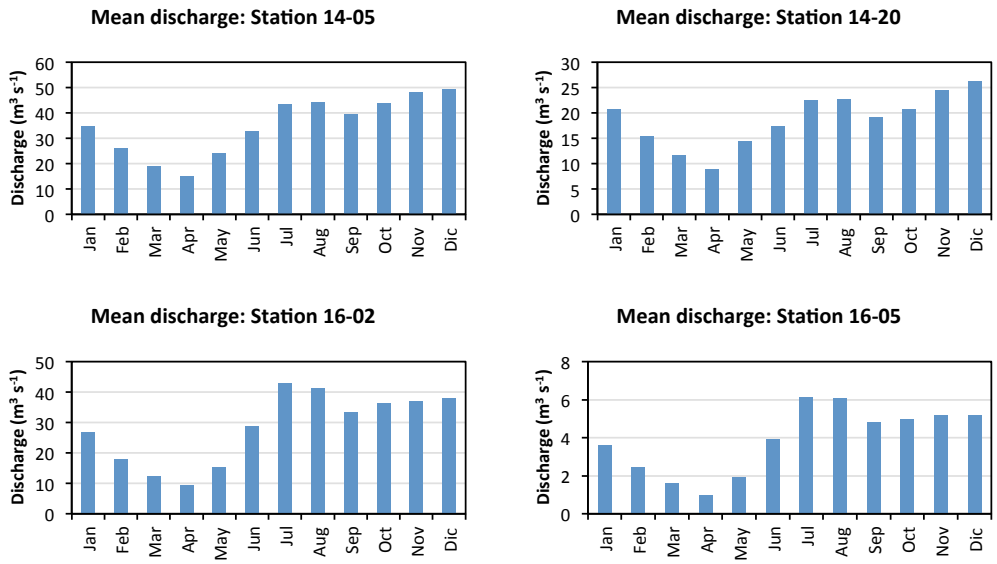


Figure 2. Mean monthly discharge recorded in fourteen gauging stations property of ICE, located in three main river basins and at San Juan and Colorado rivers.

2.3. Suspended sediment load from Costa Rican basins draining to the San Juan River

Both mean monthly suspended sediment (SS) loads and annual SS loads were calculated for the fourteen stations which are property of ICE and which are located within the basins draining to the San Juan River. These loads are based on the SS rating curves created from the SS sample data collected over time by ICE. The samples were collected applying standard sampling procedures at each of the sites where there is an ICE gauging station.

With the exception of stations 01-03 and 11-04, the information described above can be found in Table 2 and in APPENDIX A for all ICE gauging stations reported in Table 1. For the specific purposes of comparing the historical SS concentrations and loads measured at La Trinidad (01-03) station (with recording period 1973-1976) with those measured in Delta Colorado (11-04) station (recording period: 2010-2013), this information is presented separately in the sections 2.3.1 and 2.3.3. The purpose of this comparison is to assess whether there is a statistically significant difference between the SS concentrations recorded at these gauging sites that are very close to each other, in the subsequent channels of San Juan and Colorado Rivers. The comparison is performed over the same river system, in two very different periods: in the San Juan River long before Route 1856 construction (during the seventies), and in the Colorado River just after the road construction (from December 2010 onwards).

Table 2. Properties of the sediment gauging stations in the Costa Rican basins draining to San Juan River

Station code	Station name	Basin	River	No. of samples	Sampling period	SSL (t yr^{-1})	SY (t ha^{-1} yr^{-1})
01-03	La Trinidad	San Juan	San Juan	12	1974-1976	7 995 000	1.92
11-04	Delta Colorado	San Juan	Colorado	31	2010-2013	5 981 000[a]	-
12-03	Puerto Viejo	Sarapiquí	Sarapiquí	264	1970-1998	165 500	1.96
12-04	Veracruz	Sarapiquí	Toro	285	1972-2012	101 000	5.29
12-05	Bajos del Toro	Sarapiquí	Toro	137	1985-2001	50 000	6.85
12-06	Toro	Sarapiquí	Toro	117	1995-2010	20 500	5.00
12-11	San Miguel	Sarapiquí	Volcán	47	1998-2010	23 000	3.90
12-13	Río Segundo	Sarapiquí	Segundo	25	1999-2009	1 800	1.06
14-02	Jabillos	San Carlos	San Carlos	338	1967-2011	600 000	10.9
14-04	Terrón Colorado	San Carlos	San Carlos	53	1998-2009	1 300 000	8.35
14-05	Peñas Blancas	San Carlos	Peñas Blancas	308	1970-2011	157 000	5.36
14-20	Pocosol	San Carlos	Peñas Blancas	278	1980-2012	358 000	28.9
16-02	Guatuso	Frío	Frío	361	1970-2012	60 800	2.40
16-05	Santa Lucía	Frío	Venado	153	1984-2011	8 100	2.38

Note: SSL = suspended sediment load; SY = specific yield.
[a]This value is measured at the Colorado River. Hence, it is not directly comparable to the SS load at La Trinidad station (01-03).

2.3.1 Suspended sediment rating curves for the stations 01-03 La Trinidad and 11-04 Delta Colorado

Suspended sediment (SS) samples were taken by ICE in two stations (La Trinidad 01-03 and Delta Colorado 11-04, APPENDIX D and Fig. 1), which are conveniently located for the purpose of estimating possible changes in the Discharge - SS Concentration pattern in the San Juan - Colorado River system. Figure 3 presents the SS rating curves obtained for both gauging stations, along with their respective 95% confidence prediction intervals.

Given that the relationship between Discharge and SS Concentration is not a direct function of the total discharge, and also that suspended sediment concentrations do not suffer any alteration because of the bifurcation of the San Juan River into Lower San Juan and Colorado Rivers (because the average SS Concentration could be considered homogeneous in the San Juan and Colorado Rivers), it is expected that any significant changes in the Discharge - SS Concentration relationship could be evidenced by comparing the respective rating curves in these two gauging stations. However, according to Fig. 3, the rating curves for the two stations are remarkably similar, demonstrating that the Discharge - Sediment dynamics do not vary either in space (from La Trinidad site to Delta Colorado site) or in time (comparing measurements made during the 1970s to those made since December 2010). In addition, due to the high variability of the relationship between Discharge and SS Concentration, the uncertainty of the rating curves is very high, which is translated into very wide confidence bounds around the mean predicted values represented by best-fit regression curves in Fig. 3.

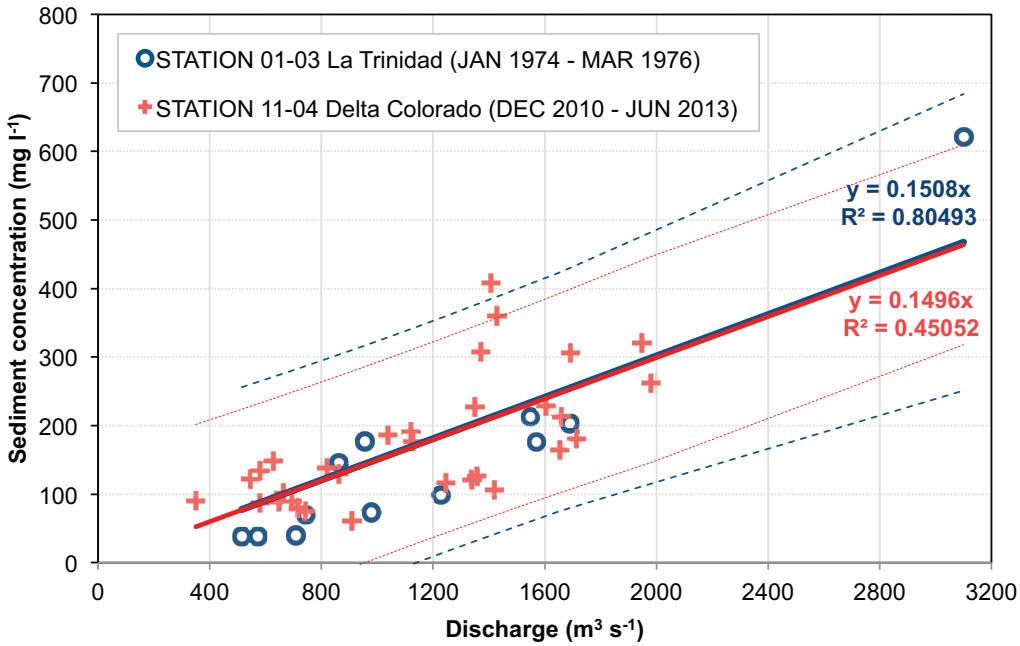


Figure 3. Suspended sediment (SS) rating curves for La Trinidad (01-03) and Delta Colorado (11-04) gauging stations. The two continuous lines represent the regression models fitted to the Discharge – SS Concentration data sets, for both gauging stations. Dotted lines represent the 95% confidence prediction interval of the mean predicted response given by each of the regression models.

The fact that the confidence regions of both rating curves overlap completely (i.e. the areas between the corresponding dotted lines in Fig. 3) indicates that with 95% confidence there is no statistical evidence that these two rating curves are different, which means that there is no scientific evidence to support any hypothesis suggesting a change in the natural relationship between Discharge and Suspended Sediment Concentration along the San Juan - Colorado River system between the two sampling periods: one long before the construction of Route 1856 (1974-1976) and the other after the construction of the road (2010-2013).

2.3.2 Seasonal behavior of the suspended sediment concentrations at Delta Colorado station (11-04)

The suspended sediment (SS) samples from Delta Colorado (11-04) station were also grouped by climatic season; this is, the dry Season (from January to April) and the rainy season (from May to December). Figure 4 presents the corresponding SS rating curves. According to the respective 95% confidence intervals, there is no statistical evidence to support the proposition that dry and rainy seasons present different Discharge - SS Concentration relationships.

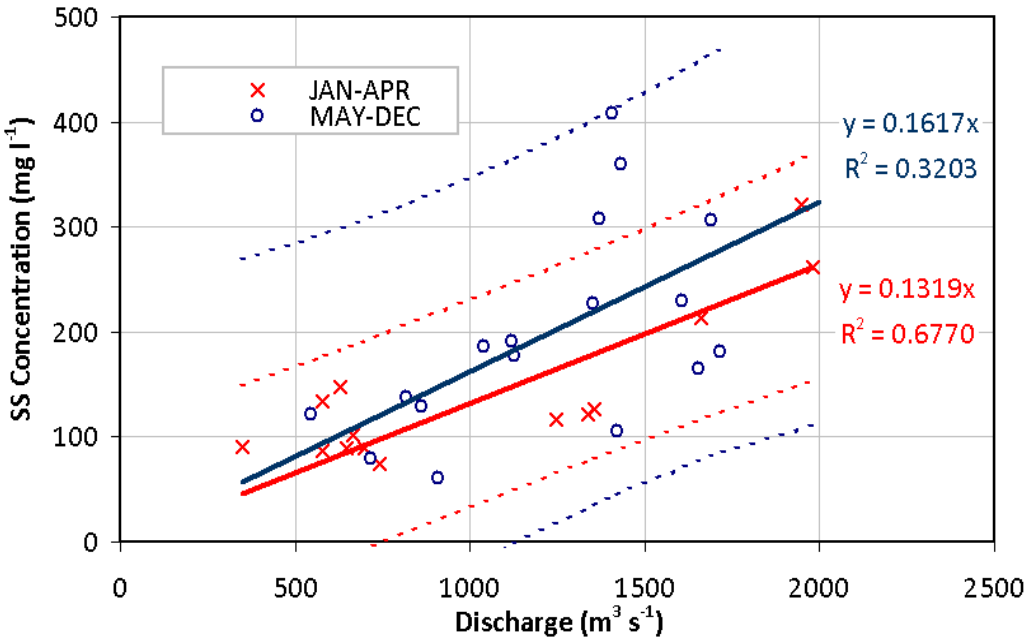


Figure 4. Suspended sediment (SS) rating curves for Delta Colorado (11-04) gauging stations, grouped by climatic season. The two continuous lines represent the regression models fitted to the Discharge – SS Concentration relationships for dry (JAN-APR) and rainy (MAY-DEC) seasons. Dotted lines represent the 95% confidence prediction interval of the mean predicted response given by each of the regression models.

2.3.3 Mean annual suspended sediment load at La Trinidad (01-03) and Delta Colorado (11-04) gauging stations

The SS loads in San Juan River were accumulated for two very different time periods: the first between 1974 and 1976 (La Trinidad station, 01-03) and the second between 2010 and 2012 (Delta Colorado station, 11-04, with data weighted to estimate SS load just in the San Juan River).

The annual suspended sediment loads were similar in both record periods, with a mean value of 7 995 000 t yr^{-1}, and a 95% confidence interval from 5 405 000 to 10 585 000 t yr^{-1}, as the estimated annual SS load in the San Juan River according to La Trinidad station (01-03) for the period 1974-1976; and a mean value of 6 573 000 t yr^{-1}, with 95% confidence interval from 5 181 000 to 7 966 000 t yr^{-1}, as the estimated SS load in the San Juan River according to Delta Colorado station (11-04) between 2010 and 2012.

The overlapping 95% confidence intervals (represented by the whiskers in Fig. 5) around both mean annual loads, indicate that there is no statistical evidence that the mean annual SS loads are significantly different before and after construction of Route 1856.

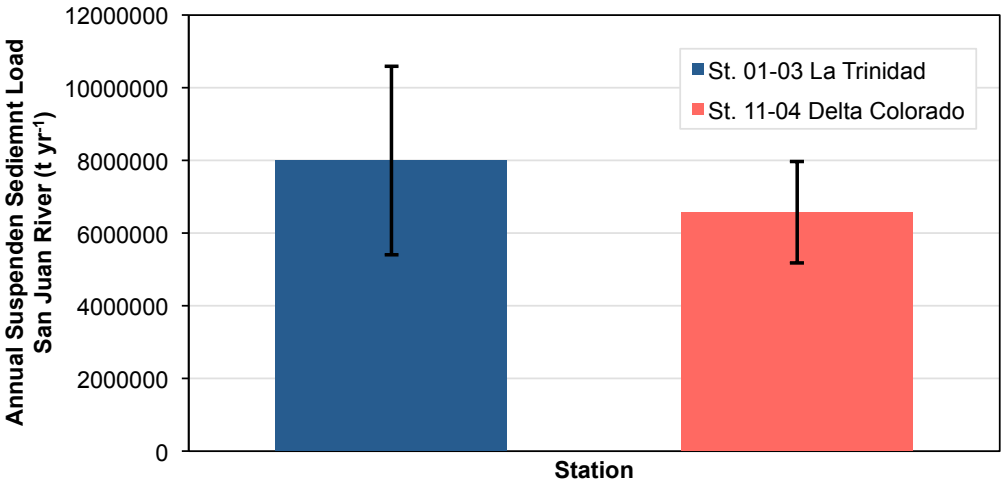


Figure 5. Mean annual suspended sediment load at La Trinidad station (01-03), which is located directly in the San Juan River; compared to the weighted estimation of the respective load in the San Juan River, obtained from the measurements at Delta Colorado station (11-04), which is located in the Colorado River just after the bifurcation of these two rivers. The whiskers represent the bounds of a 95% confidence interval for both annual means.

2.4. Bed-load sediment from Costa Rican basins draining to the San Juan River

One hundred and twenty two bed-load samples were taken between December 2010 and June 2013 at three different sites: the mouths of San Carlos and Sarapiquí Rivers, and the Delta Colorado station (11-04). All these samples were analysed in the Chemical Laboratory of the Department of Hydrology and the corresponding particle size distributions are reported in the APPENDIX E. The analysis of the samples demonstrates that in this river system the bed-load sediment is almost entirely composed of sand (Fig. 6). For that reason, the Einstein bed-load function for sediment transport (Einstein, 1950) was used to estimate the annual bed-load at two sites: the Lower San Juan River and the Colorado River, just after the bifurcation of the main channel of San Juan River. The detail of the calculations can be found in APPENDIX F.

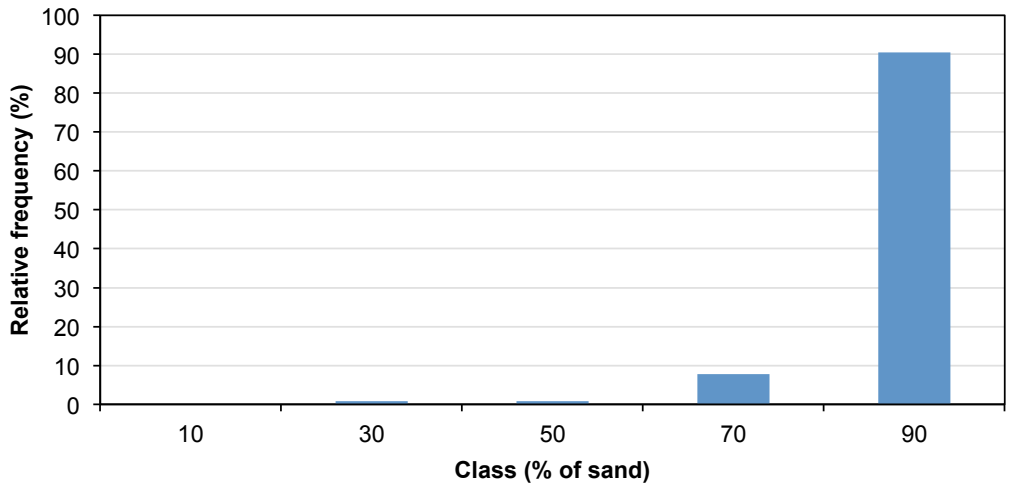


Figure 6. Frequency distribution of the sand percentage for all bed-load samples.

Applying the Einstein function to the 115 bed-load samples taken at Delta Colorado (11-04) station, a d_{65} mean value of 0.584 mm, and hydraulic properties representing the cross section of the 11-04 station, a bed-load sediment rating curve was created for all particles with a size larger than 0.063 mm (Fig. 7). Then the bed-load sediment regime was calculated (Fig. 8) based on both the bed-load rating curve and the hydrograph for the 11-04 station reported in the APPENDIX C.

The resulting bed-loads are: 2 488 000 t yr^{-1} flowing through the Colorado River, with estimated lower and upper variability bounds of 2 340 000 t yr^{-1} and 2 595 000 t yr^{-1}. In addition, a bed-load of 71 000 t yr^{-1} was estimated to flow through the Lower San Juan River, with lower and upper bounds of 66 600 t yr^{-1} and 73 800 t yr^{-1}, respectively. Therefore, the total bed-load in the main channel of the San Juan River should be equal to the sum of the loads estimated for the Colorado and Lower San Juan Rivers, which amounts to 2 559 000 t yr^{-1}.

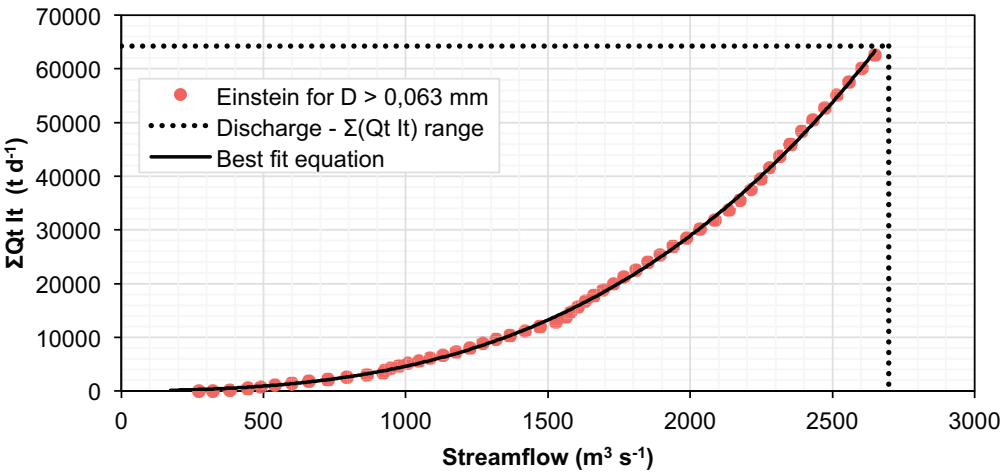


Figure 7. Bed-load sediment rating curve for particles larger than 0.063 mm at the Delta Colorado (11-04) station.

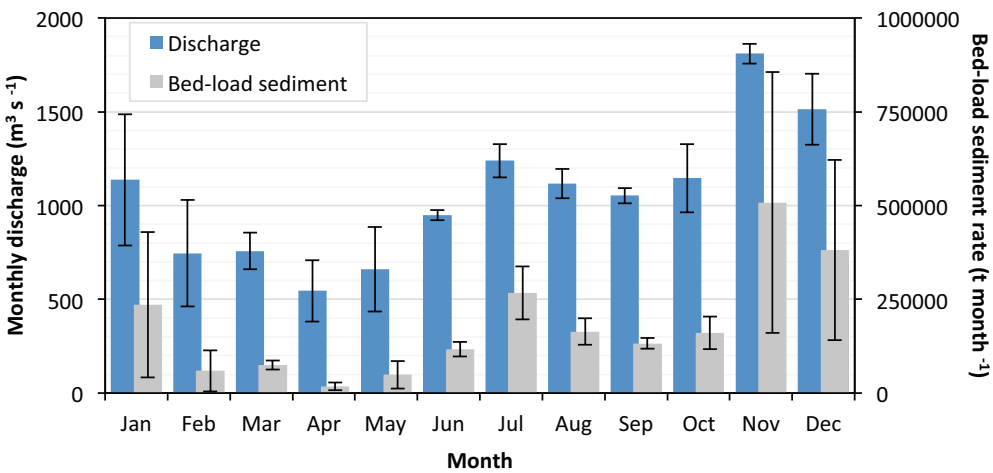


Figure 8. Streamflow and bed-load sediment load regimes: Station 11-04 Delta Colorado (Dec 2010 - Jul 2013).

The same methodology was employed to estimate the bed-load transport capacity for particles larger than 0.063 mm in the Lower San Juan River. A hydrograph for the Lower San Juan was estimated from the hydrograph recorded at the Delta Colorado station (11-04), applying a discharge capacity ratio based on the discharge balance to be presented in Chapter 3. In addition, it was assumed that just downstream of the bifurcation the particle size distribution remains similar in the cross sections of Colorado and Lower San Juan Rivers, which allows use in the latter of the same value of d_{65} recorded at the Delta Colorado (11-04) station. Finally, a value of 100 m

was directly extracted from recent, georeferenced satellite images, as the representative width of the San Juan River at the site of interest.

The bed-load sediment rating curve for particle sizes larger than 0.063 mm was then produced for the Lower San Juan River (Fig. 9), and this was then used to estimate the bed-load regime, which is presented in Fig. 10 along with the corresponding discharge regime. According to this, the annual bed-load sediment in the Lower San Juan River amounts to 71 000 t yr^{-1}.

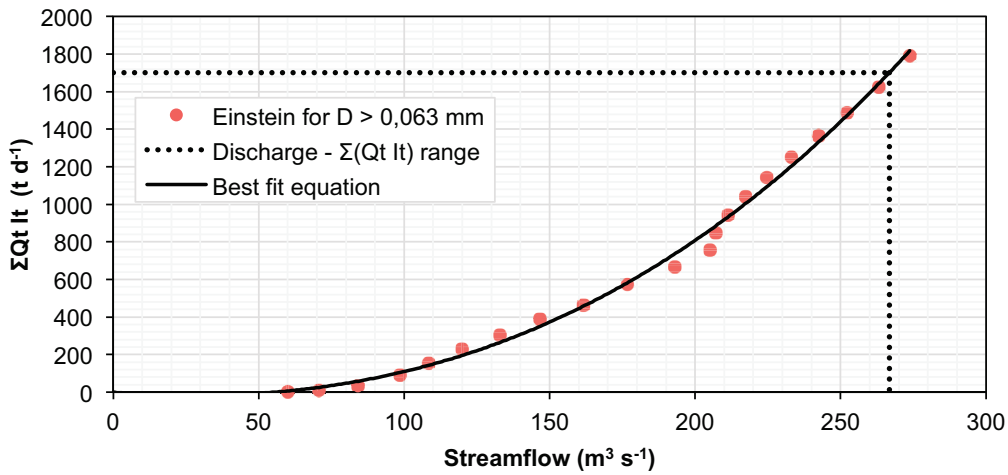


Figure 9. Bed-load sediment rating curve for particles larger than 0.063 mm. Lower San Juan River.

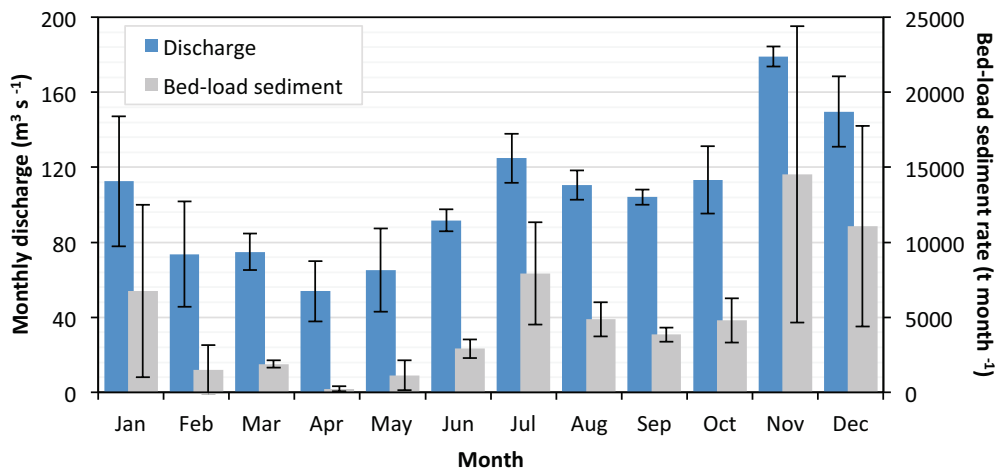


Figure 10. Streamflow and bed-load sediment load regimes: Lower San Juan River (Dec 2010 - Jul 2013).

3. DISCHARGE BALANCE IN THE SAN JUAN - COLORADO RIVER SYSTEM

A discharge balance was produced for the San Juan - Colorado River system, taking into account the discharge inputs from the Lake Nicaragua and all the main flow tributaries from Costa Rica and Nicaragua. For this purpose, the mean annual discharge presented in Table 1 was used, either directly: for the first three gauging stations (located in the San Juan River); or reprocessed using the Area-Precipitation method in order to estimate the input discharge (from the Costa Rican drainage basins to the San Juan River). The results of this latter process are reported in Table 3 below.

Table 3. Discharge from Costa Rican river basins draining to the San Juan - Colorado River (ICE, 2010)

Basin	Area (km^2)	Mean annual discharge	
		($m^3\ s^{-1}$)	%
Frío River	1556	112	14
Pocosol River and others (Medio Queso, etc.)	1256	58	7
Infiernito River	561	36	5
San Carlos River[a]	2735	209	27
Cureña River	328	25	3
Sarapiquí River[b]	2762	343	44
Total	9198	783	100

[a]The area and discharge of San Carlos River basin exclude the sub-basin of Lake Arenal. [b]The area and discharge of Sarapiquí River basin were corrected in order to take into account the change in the course of the Sucio River, which currently drains to Sarapiquí basin.

Combining the discharge information provided in Tables 1 and 3, the discharge balance of the San Juan - Colorado River system is presented in Fig. 11. In addition, a summary of the inputs from Lake Nicaragua, Costa Rican and Nicaraguan basins is given in Table 4.

Table 4. Discharge values from Costa Rican and Nicaraguan sides, draining to San Juan - Colorado River

Source	Mean annual discharge		
	($m^3\ s^{-1}$)	Percentage (%)	
		ILN	ELN
Lake Nicaragua	185[a]	16	-
Costa Rican basins	783	70	83
Nicaraguan basins	155[b]	14	17
Total	1123	100	100

Note: ILN = including Lake Nicaragua; ELN = excluding Lake Nicaragua.
[a]This value was estimated as the difference between the discharge of San Juan River at San Carlos station (INETER, 2002) and the input from the Frío River basin (ICE, 2010). [b]This value was estimated as the difference between the discharge of San Juan River at La Trinidad station (ICE, 2011) and the sum of inputs from Lake Nicaragua and from all Costa Rican river basins

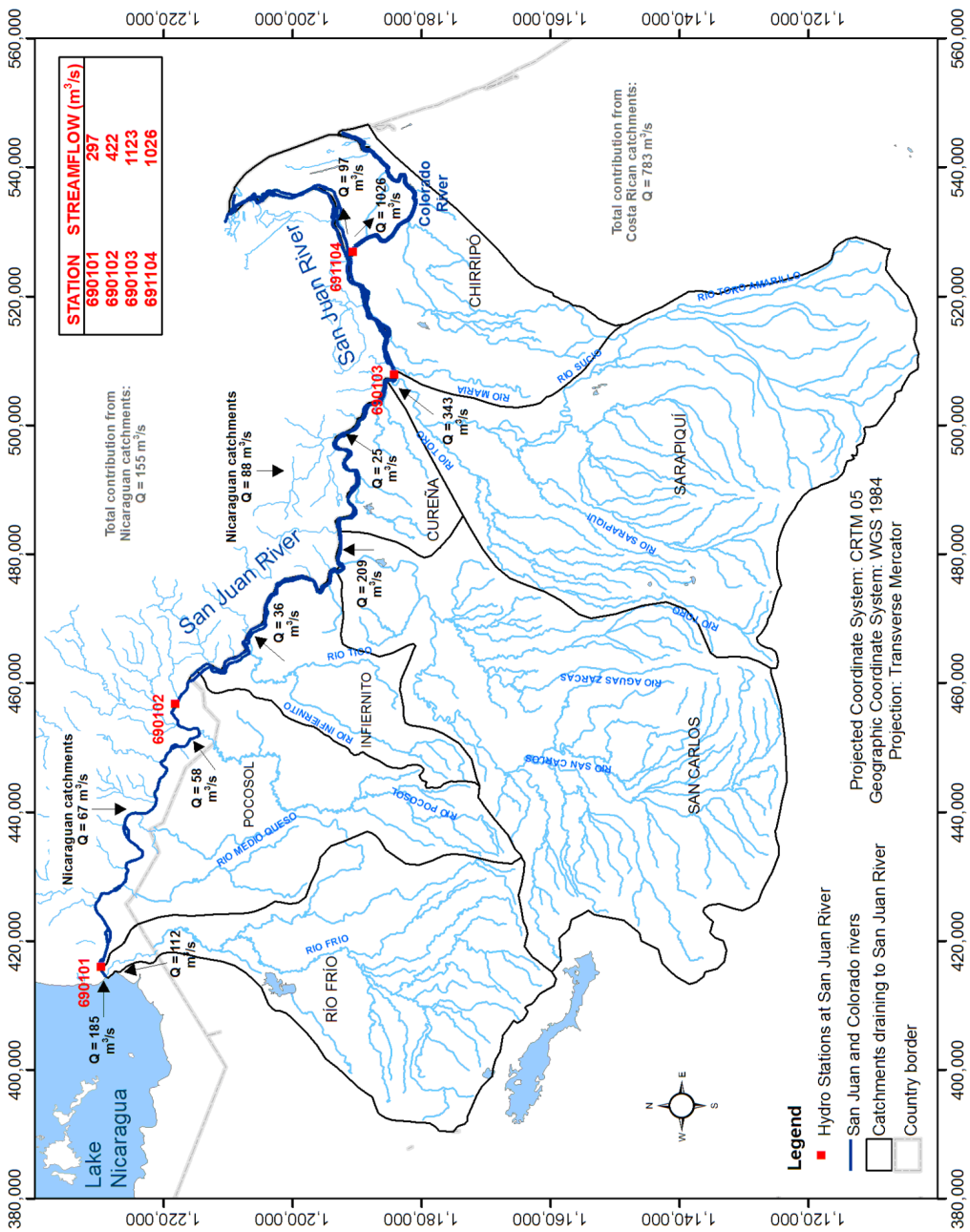


Figure 11. Discharge balance in the San Juan - Colorado River system.

4. HYDROLOGICAL REGIME IN THE TRIBUTARY BASINS DRAINING FROM COSTA RICA TO THE SAN JUAN RIVER, BEFORE AND AFTER THE CONSTRUCTION OF ROUTE 1856

In order to establish the hydrological (discharge) regime of the system of basins draining to the San Juan River from Costa Rica, it was necessary to identify not only the main river basins, but also the minor ones flowing directly to the San Juan River. Figure 12 presents this hydrological system, which is constituted by seven major basins and eighty minor basins, the latter being highlighted in grey. The delineation of the main basins was based on a digital elevation model, while for the minor basins the Hydrodem package (Leblois and Sauquet, 2000) was applied with the purpose of manually correcting the flow paths in flat regions, a frequent problem for the delineation of small basins near to natural river banks or floodplains. Once all these basins were identified, an analysis of the increase in the impermeable area of each basin due to the construction of Route 1856 was carried out (to be presented in Section 4.1), to determine pre- and post-Route 1856 hydrological regimes for all the rivers and streams flowing to the San Juan River from Costa Rican basins (Section 4.2).

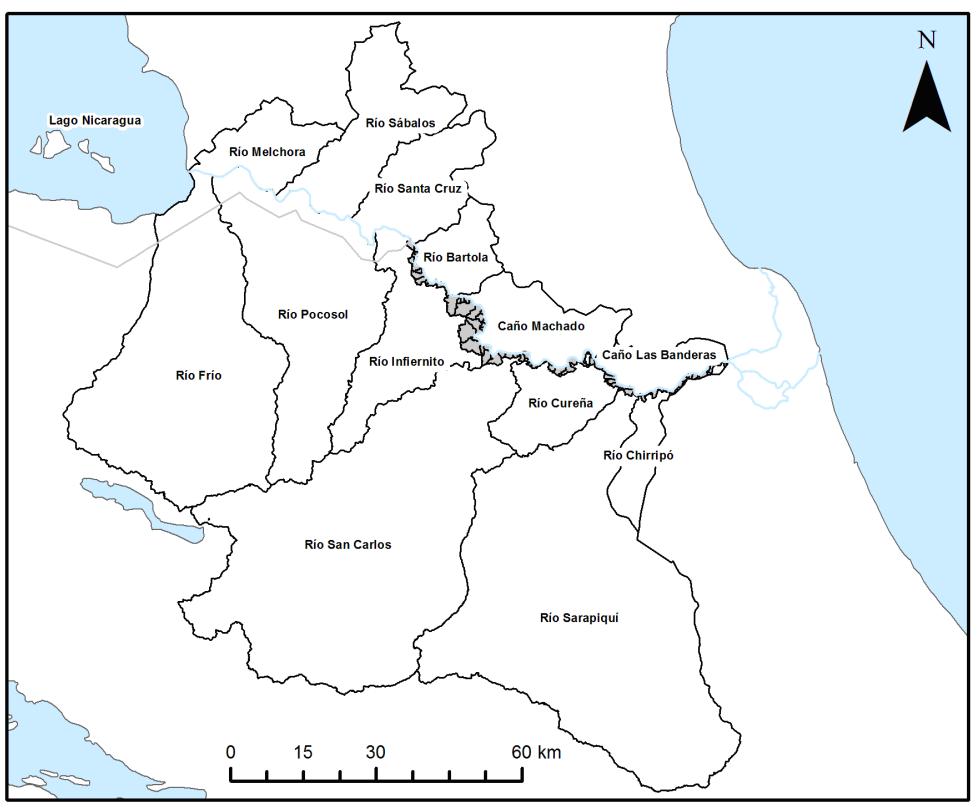


Figure 12. Tributary basins draining to the San Juan River.

4.1. Impermeable areas in the basins draining to the RSJ

Table 5 presents the increase in the impermeable areas due to construction of Route 1856 (conservatively assuming that the road surface is 100% impermeable) for all basins and microbasins draining to the San Juan River from Costa Rica (Fig. 12). To do this, a digital polygon was used to represent the Route (including not just the road surface but the whole right-of-way). The overall increase in the impermeable area for all (major and micro) basins added together amount to only 0.08%.

Table 5. Maximum increase in the impermeable area of the basins draining to SJR from C. Rica

Basin	Area (km^2)	Imperm. Area (km^2)	Change (%)	Basin	Area (km^2)	Imperm. Area (km^2)	Change (%)
Microbasins between Mojón II and Delta C.R.				*Microbasins between Mojón II and Delta C.R.*			
Basin 01	2.00	0.109	5.40	Basin 46	0.88	0.012	1.33
Basin 02	1.05	0.067	6.40	Basin 47	0.42	0.005	1.25
Basin 03	0.41	0.014	3.30	Basin 48	0.70	0.006	0.80
Basin 04	1.05	0.047	4.50	Basin 49	0.39	0.001	0.36
Basin 05	1.45	0.019	1.30	Basin 50	1.68	0.030	1.76
Basin 06	2.20	0.030	1.40	Basin 51	0.61	0.020	3.33
Basin 07	0.93	0.006	0.60	Basin 52	1.57	0.011	0.69
Basin 08	3.30	0.124	3.70	Basin 53	0.50	0.007	1.47
Basin 09	2.68	0.033	1.20	Basin 54	0.92	0.011	1.20
Basin 10	0.40	0.021	5.30	Basin 55	0.56	0.005	0.96
Basin 11	1.69	0.078	4.60	Basin 56	4.93	0.080	1.63
Basin 12	1.12	0.122	10.90	Basin 57	1.66	0.034	2.08
Basin 13	0.69	0.097	14.00	Basin 58	1.60	0.033	2.07
Basin 14	0.61	0.073	12.10	Basin 59	1.16	0.037	3.16
Basin 15	8.12	0.117	1.40	Basin 60	1.47	0.028	1.88
Basin 16	1.01	0.025	2.40	Basin 61	1.70	0.092	5.42
Basin 17	0.83	0.025	3.00	Basin 62	0.76	0.029	3.78
Basin 18	1.08	0.067	6.20	Basin 63	0.40	0.013	3.26
Basin 19	9.77	0.081	0.80	Basin 64	3.53	0.035	0.98
Basin 20	0.68	0.076	11.30	Basin 65	2.83	0.093	3.29
Basin 21	5.24	0.055	1.00	Basin 66	2.43	0.051	2.10
Basin 22	0.68	0.050	7.40	Basin 67	0.38	0.016	4.34
Basin 23	2.09	0.052	2.50	Basin 68	1.26	0.067	5.31
Basin 24	0.86	0.009	1.00	Basin 69	0.68	0.029	4.24
Basin 25	0.63	0.010	1.60	Basin 70	1.49	0.004	0.30
Basin 26	5.50	0.018	0.30	Basin 71	1.58	0.055	3.47
Basin 27	10.27	0.006	0.10	Basin 72	1.48	0.064	4.32
Basin 28	0.91	0.040	4.40	Basin 73	2.08	0.016	0.77
Basin 29	9.12	0.035	0.40	Basin 74	1.62	0.006	0.35
Basin 30	1.65	0.109	6.60	Basin 75	2.63	0.100	3.80
Basin 31	4.37	0.040	0.90	Basin 76	0.40	0.006	1.56
Basin 32	1.49	0.017	1.20	Basin 77	2.21	0.005	0.23
Basin 33	0.56	0.005	0.87	Basin 78	0.58	0.003	0.47
Basin 34	0.87	0.033	3.84	Basin 79	0.69	0.040	5.74
Basin 35	0.76	0.036	4.70	Basin 80	1.32	0.025	1.91
Basin 36	0.44	0.028	6.35	*Major Costa Rican basins along San Juan River*			
Basin 37	1.71	0.063	3.70	Frío River	1 746	0.00	0.00
Basin 38	1.14	0.039	3.45	Pocosol River	1 224	0.93	0.08
Basin 39	1.07	0.031	2.92	Infiernito River	609	1.99	0.33
Basin 40	0.71	0.041	5.72	S. Carlos River	2 644	0.34	0.01
Basin 41	1.88	0.051	2.73	Cureña River	343	0.76	0.22
Basin 42	0.97	0.020	2.03	Sarapiquí River	2 743	0.06	0.00
Basin 43	0.51	0.034	6.63	Chirripó River	255	0.41	0.16
Basin 44	1.15	0.009	0.77	*Summary*			
Basin 45	0.40	0.003	0.74	Total	9564	4.50	0.05

4.2. Hydrological regime of all the rivers and streams flowing to the San Juan River from Costa Rican basins: Evaluation of Route 1856

Synthetic hydrographs were generated for the period 1976-2013 based on El Bum (69-578) station's daily precipitation series using the HEC-HMS model (U.S. Army Corps of Engineers), the Curve Number (CN) runoff-precipitation relationship model of the Soil Conservation Service (SCS) and the unit hydrograph proposed by that same agency. Curve Numbers were estimated for the conditions before and after Route 1856 construction according to land use maps provided by ICE and Dr. Andreas Mende, and reference tables proposed by Hawkins et al. (2009) as an area-weighted average for each basin; antecedent moisture condition (ACM) II, corresponding to average conditions, was selected. For each microbasin, initial abstractions (Ia) and time of concentration (tc) were calculated based on CN and morphometric parameters (area, average slope, length of the longest flow path, etc.); lag time (tg) was assumed as 0.6 tc, according to SCS Lag Time equation.

In order to quantify hydrological impacts due to Route 1856 construction, discharge regimes were calculated for the microbasin system in Costa Rica between Mojón II and the Delta based on El Bum (69-578) station's 38-year daily precipitation series. Two hydrological models were constructed to perform hydrologic simulation of system's response to rainfall with and without Route 1856. Table 6 and Fig. 13 present the results of these simulations and illustrate any hydrological impact to be expected due to construction of Route 1856, in terms of the monthly discharge regime.

Table 6. Discharge regime for the microbasins draining to the San Juan River, modelled using HEC-HMS from 1976 to 2013, or conditions with and without the presence of Route 1856

Month	Discharge without Road ($m^3\ s^{-1}$)		Discharge with Road ($m^3\ s^{-1}$)		Difference ($m^3\ s^{-1}$)
	Mean value	Error bound	Mean value	Error bound	
January	16.46	1.13	16.47	1.42	3.81×10^{-3}
February	11.63	0.81	11.63	1.20	6.39×10^{-4}
March	8.06	0.64	8.06	1.01	1.45×10^{-4}
April	8.87	0.76	8.87	1.16	1.03×10^{-4}
May	13.70	0.86	13.70	1.01	1.38×10^{-4}
June	20.46	1.23	20.46	1.43	1.37×10^{-4}
July	25.84	1.31	25.84	1.59	1.69×10^{-4}
August	20.05	1.10	20.05	1.33	5.51×10^{-5}
September	15.04	0.90	15.04	1.35	3.76×10^{-5}
October	17.05	1.02	17.05	1.20	2.72×10^{-5}
November	24.45	1.32	24.45	1.46	2.76×10^{-5}
December	23.09	1.35	23.09	1.54	1.50×10^{-5}

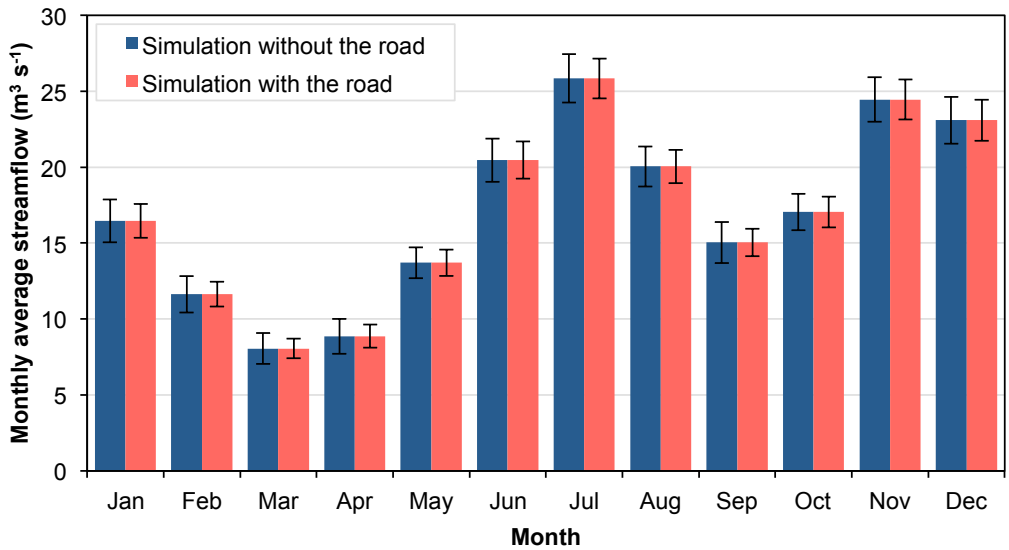


Figure 13. Discharge regime for the microbasins draining to the San Juan River, modelled using HEC-HMS from 1976 to 2013, for conditions with and without the presence of Route 1856.

In order to estimate the discharge regimes of the major Costa Rican basins along San Juan River prior to construction of the Road, monthly discharge time series from four stations, over the time period 1971-2006, were studied: Guatuso (16-02) station, located in the Frio River basin; Terrón Colorado (14-04) station, located in the San Carlos River basin; and, finally, Puerto Viejo (12-03) and Veracruz (12-04) stations, both located in the Sarapiquí River basin. The regime for the whole system was calculated based on the individual regimes of these four catchments and then corrected by using the Area-Precipitation method and a factor derived from the discharge balance presented in Chapter 3. The discharge regime of the major Costa Rican basins along San Juan River, corresponding to post Route 1856 conditions, was calculated by adding the absolute differences in discharge, estimated for the microbasin system, to Pre-Route regime estimated previously. The results are shown in Table 7 and Fig. 14.

Table 7. Discharge regime for all the basins (micro and macro) draining to the San Juan River. Times series generated from 1971 to 2006 for pre- and post-Route 1856 conditions

Month	Discharge ($m^3 s^{-1}$)			Absolute difference (m^3/s)	Relative difference (%)
	PreRoute	PostRoute	Error bounds		
January	765.30	765.44	103.7	3.81×10^{-3}	4.97×10^{-4}
February	535.56	535.59	54.8	6.39×10^{-4}	1.19×10^{-4}
March	400.64	400.64	34.9	1.45×10^{-4}	3.62×10^{-5}
April	360.78	360.79	40.2	1.03×10^{-4}	2.86×10^{-5}
May	561.09	561.09	76.8	1.38×10^{-4}	2.45×10^{-5}
June	781.79	781.80	59.2	1.37×10^{-4}	1.75×10^{-5}
July	1000.46	1000.47	60.5	1.69×10^{-4}	1.69×10^{-5}
August	1001.94	1001.94	53.0	5.51×10^{-5}	5.50×10^{-6}
September	894.23	894.23	35.9	3.76×10^{-5}	4.21×10^{-6}
October	974.93	974.93	54.3	2.72×10^{-5}	2.79×10^{-6}
November	1069.41	1069.41	100.4	2.76×10^{-5}	2.58×10^{-6}
December	1043.77	1043.78	118.6	1.50×10^{-5}	1.44×10^{-6}

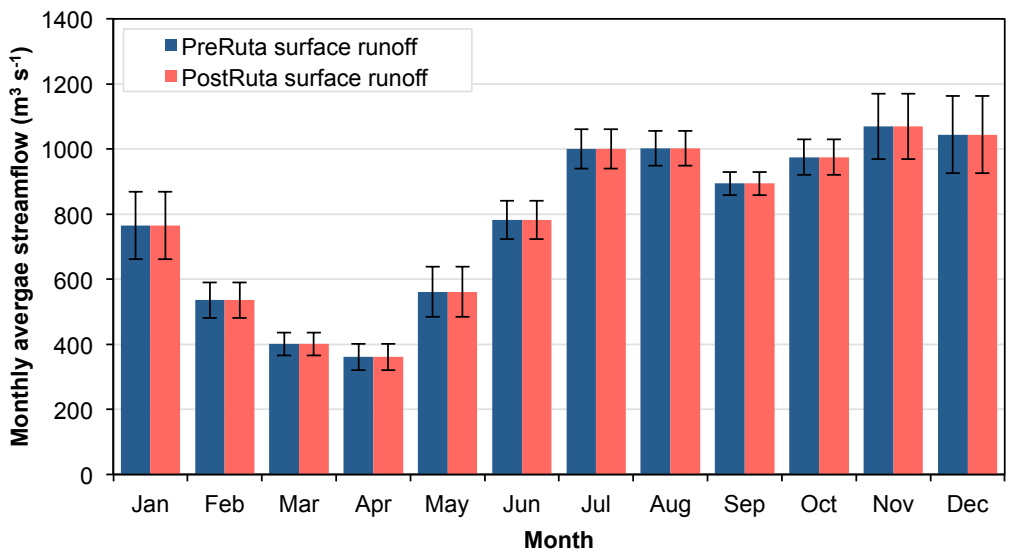


Figure 14. Discharge regime for all the basins (micro and macro) draining to the San Juan River. Times series generated from 1971 to 2006 for pre- and post-Route 1856 conditions.

5. DISTRIBUTED EROSION AND SEDIMENT YIELD IN THE SAN JUAN - COLORADO RIVER SYSTEM

Potential soil erosion, sediment yield and delivery ratio from major basins draining directly to the San Juan river from both Costa Rica (Frío, Pocosol, Infiernito, San Carlos, Cureña, Sarapiquí y Chirripó) and Nicaragua (Melchora, Sábalos, Santa Cruz, Bartola, Caño Machado y Caño Las Banderas) were estimated using the CALSITE model (Bradbury et al., 1993). CALSITE (Calibrated Simulation of Transported Erosion) is a software package that applies the USLE (Universal Soil Loss Equation; Wischmeier and Smith, 1960):

$$A = R\,K\,LS\,CP \qquad (1)$$

where R = rainfall erosivity factor, K = soil erodability factor, LS = topographic factor and CP = land use and land management factor,

to predict soil erosion within a basin together with estimation of the amount of transported material which contributes to sediment yield from the basin. CALSITE makes use of Geographic Information System (GIS) techniques to map and display soil erosion and sources of sheet/rill sediment yield within a basin (see H.1. in APPENDIX H). It is intended as a basin management and planning tool to identify current sources of erosion and sediment yield and to predict the effects of changes in land management on erosion and sedimentation. CALSITE works in three stages: (a) the calculation of total (potential) soil erosion; (b) the calibration of sediment delivery function using either observed sediment measurements or a predefined delivery function; and (c) the calculation and mapping of transport of eroded sediment or sediment yield.

Because CALSITE uses a GIS approach, map information on rainfall, land use, soils, topography and agricultural practices was required. Digital maps of rainfall erosivity, mean annual rainfall, land use and land management, soil erodability and digital elevation and slope models were generated for both Costa Rican major basins and Nicaraguan major basins draining directly to the San Juan River. Both input and output digital maps generated for this purpose are presented in the Section H.2 of the APPENDIX H. Two different sediment delivery functions were calibrated using sediment data from hydrological gauging stations located in the San Carlos and Sarapiquí River basins. An average delivery function was then calculated and used to estimate sediment yields across major Costa Rican and Nicaraguan basins draining to the San Juan River.

Results for Costa Rican basins are present in Table 8, Figs. 15, 16 and 17. The whiskers in the following graphs in each case indicate 95% confidence bands.

Table 8. Estimate sediment yields for Costa Rican basins

Basin	DR	SPE (t ha^{-1} yr^{-1})	PEL (t yr^{-1})	SSY (t ha^{-1} yr^{-1})	SY (t yr^{-1})
Major Costa Rican river basins draining directly to the San Juan River					
Frío River	0.39	3.96	691 000	1.54	269 000
Pocosol River	0.20	2.01	246 000	0.40	49 000
Infiernito River	0.38	3.35	204 000	1.28	78 000
San Carlos River	0.56	12.38	3 273 000	6.90	1 824 000
Cureña River	0.41	1.65	57 000	0.67	23 000
Sarapiquí River	0.11	15.68	4 301 000	1.67	458 000
Chirripó River	0.24	4.43	113 000	1.07	27 000
Summary for the entire Costa Rican area that drains directly to the San Juan River					
Total	0.31	9.29	8 885 000	2.85	2 728 000

Note: DR = delivery ratio; SPE = specific potential erosion; PEL = potential erosion load; SSY = specific sediment yield; SY = sediment yield.

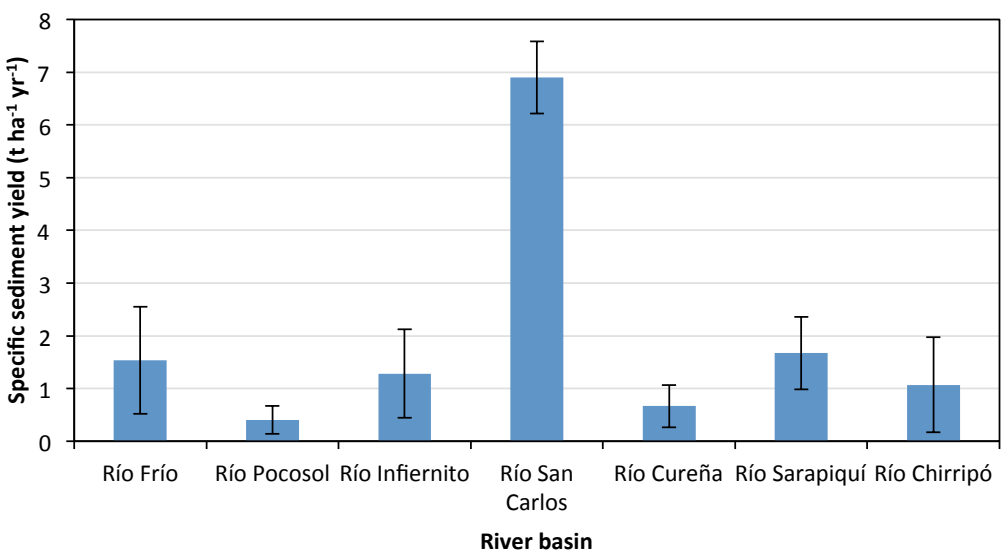


Figure 15. Specific sediment yields for Costa Rican basins draining to the San Juan River.

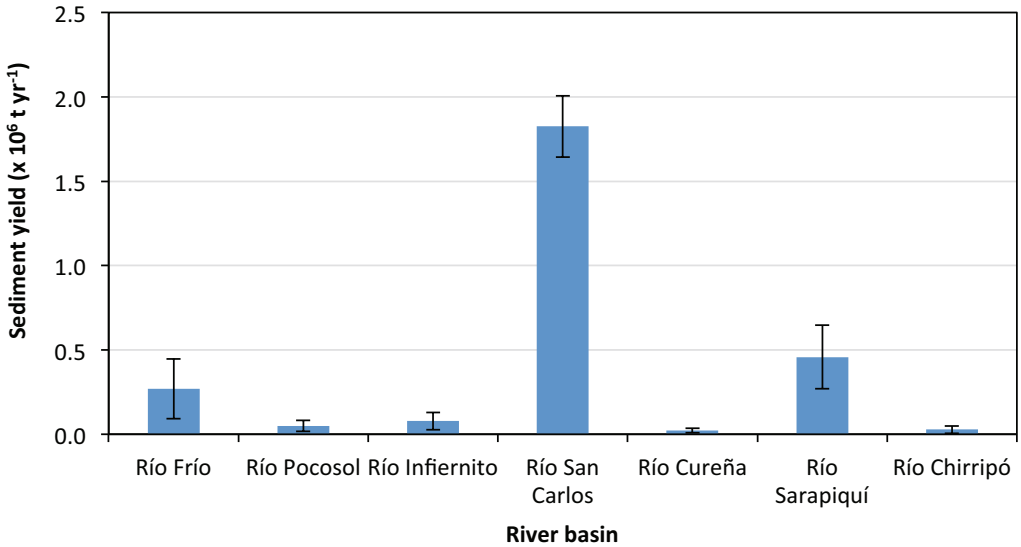


Figure 16. Total sediment yields for Costa Rican basins draining to the San Juan River.

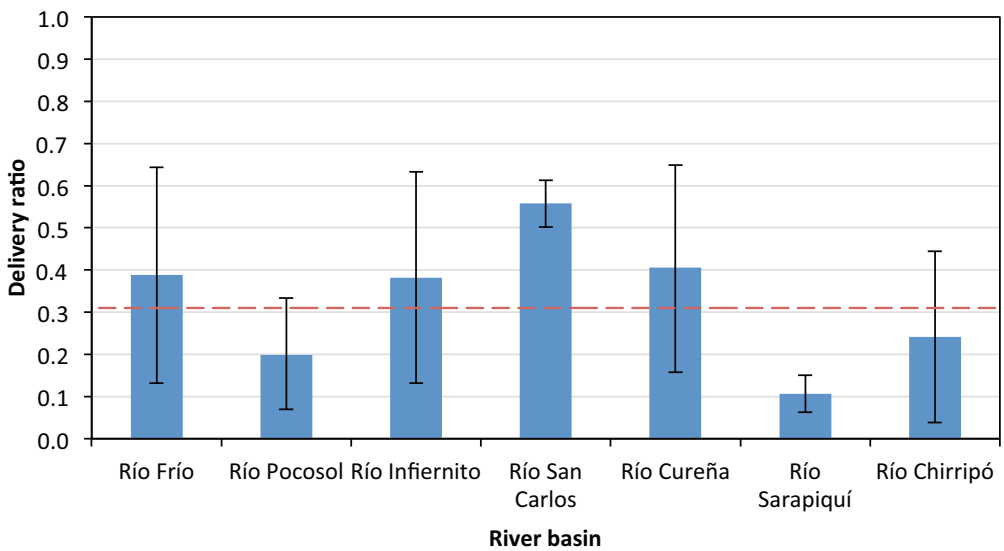


Figure 17. Delivery ratios for Costa Rican basins draining to the San Juan River. The dotted line represents the mean value for the whole drainage system (which is equal to 0.31)

As mentioned above, sediment yields produced for Nicaraguan basin systems were estimated using the average delivery function calibrated using data from the San Carlos and Sarapiquí River basins. Results are presented in Table 9 and in Figs. 18, 19 and 20.

Table 9. Estimate sediment yields for Nicaraguan basins

Basin	DR	SPE (t ha^{-1} yr^{-1})	PEL (t yr^{-1})	SSY (t ha^{-1} yr^{-1})	SY (t yr^{-1})
Major Nicaraguan river basins draining directly to the San Juan River					
Melchora River	0.24	39.05	1 177 000	9.22	278 000
Sábalos River	0.28	22.47	1 312 000	6.27	366 000
Santa Cruz River	0.35	16.66	691 000	5.88	244 000
Bartola River	0.58	1.84	40 000	1.07	23 000
Machado Creek	0.35	3.44	124 000	1.21	44 000
LasBanderas Creek	0.35	4.87	88 000	1.72	31 000
Summary for the entire Nicaraguan area that drains directly to the San Juan River					
Total	0.29	16.65	3 432 000	4.78	986 000

Note: DR = delivery ratio; SPE = specific potential erosion; PEL = potential erosion load; SSY = specific sediment yield; SY = sediment yield.

It is important to note that even though potential erosion and sediment yields from Costa Rican basins are larger than those of Nicaragua (because of the much larger drainage area on the Costa Rican side), the specific potential erosion and specific sediment yield (that is, the erosion and sediment yield per unit of area) is much larger on Nicaragua's side (Fig. 15 versus Fig. 18). This indicates that Nicaraguan basins draining to the San Juan River produce much more sediment per unit area than those in Costa Rica.

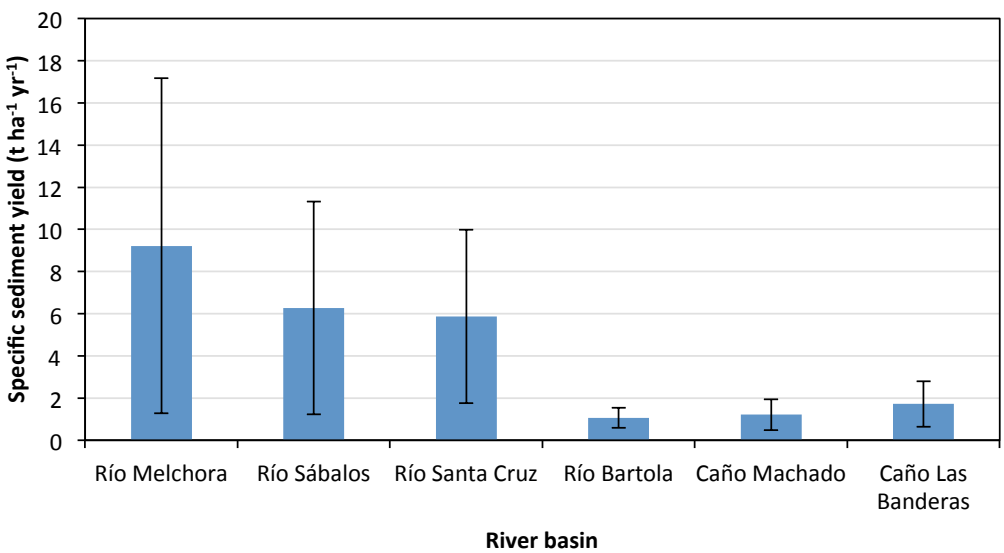


Figure 18. Specific sediment yields for Nicaraguan basins draining to the San Juan River.

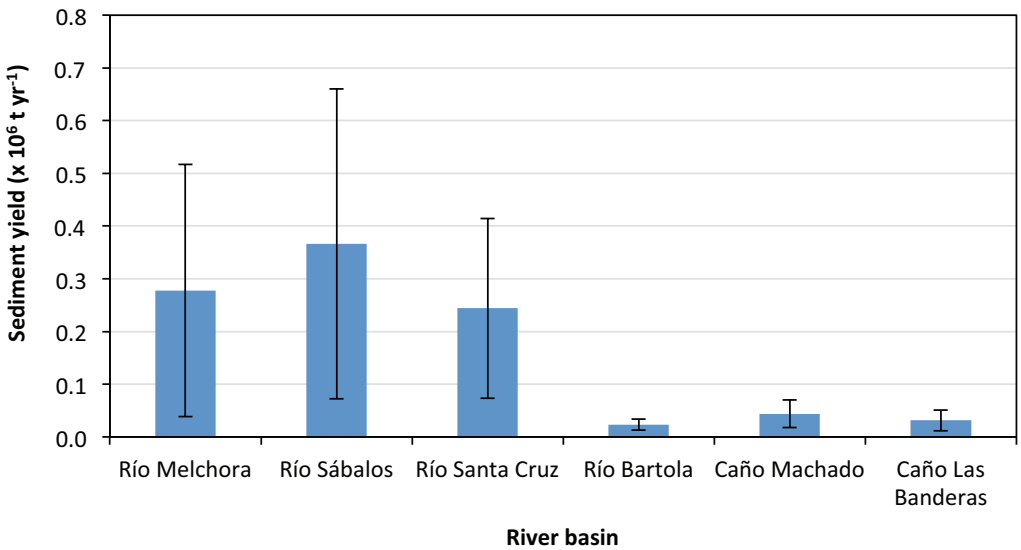


Figure 19. Total sediment yields for Nicaraguan basins draining to the San Juan River.

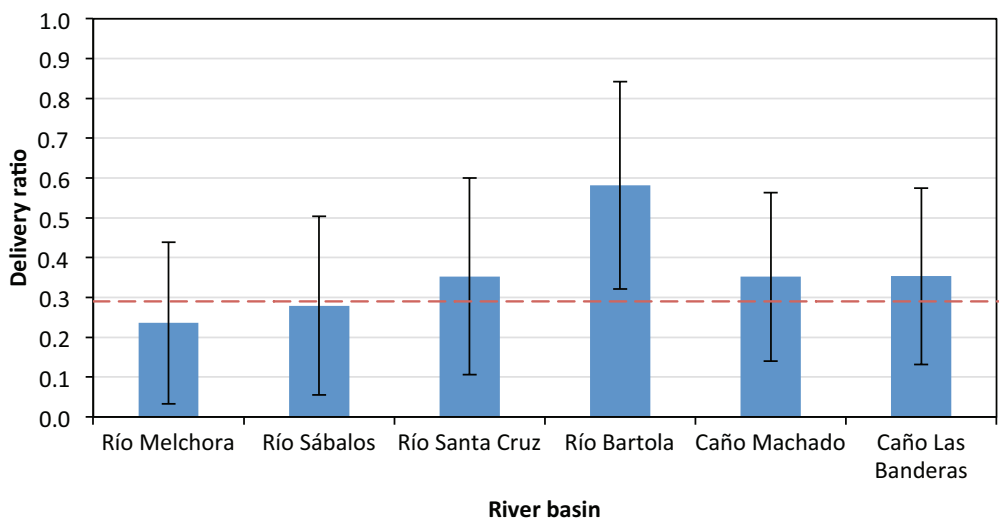


Figure 20. Delivery ratios for Nicaraguan basins draining to the San Juan River. The dotted line represents the mean value for the whole drainage system (which is equal to 0.29).

6. SEDIMENT BALANCE IN THE SAN JUAN - COLORADO RIVER SYSTEM, BEFORE AND AFTER CONSTRUCTION OF ROUTE 1856

Once all the suspended sediment (SS) input loads flowing to the San Juan River from Costa Rican and Nicaraguan basins were estimated by modelling (as reported in the previous section), the sediment balance can be established – provided the sediment loads in the San Juan River just upstream of the bifurcation at the Delta are known. It must be noted the Delta Colorado (11-04) station provides the main and most reliable estimation of sediment load for establishing this balance (because it integrates all the sediment flows entering the San Juan River system and because it has been directly measured by ICE, respectively). Also it must be noted that the sediment load measurements at station 11-04 used to estimate the load were performed after construction of Route 1856. If follows that the sediment balance produced here on the basis of those measurements necessarily represents hydrological and sedimentological conditions after construction of Route 1856. Therefore, after an estimate of the additional sediment yield contribution due to the construction of Route 1856 is made in Section 6.2, a second sediment balance is generated by subtracting this contribution to represent the original balance pre-Route 1856.

6.1. Total annual sediment load after construction of Route 1856

Based on measured records for the Delta Colorado station (11-04) and assuming that sediment concentrations are homogeneous, it was calculated in Section 2.3.3 that the SS load in the San Juan River just upstream of the Delta is 6 573 000 t yr^{-1} and 5 981 000 t yr^{-1} in the Colorado River, implying that 592 000 t yr^{-1} (the difference between these two loads) passes through the Lower San Juan River. In Section 2.4 the bed-loads of sediment in the Colorado and Lower San Juan Rivers were estimated as 2 488 000 and 71 000 t yr^{-1}, respectively. Adding these together, the bed-load in the San Juan River just upstream of the Delta is then estimated to be 2 559 000 t yr^{-1}. According to the previous figures, the total sediment load (that is suspended load plus bed-load) in the San Juan River amounts to 9 133 000 t yr^{-1}, which is divided at the Delta into 8 470 000 t yr^{-1} passing through the Colorado River and 663 000 t yr^{-1} passing through the Lower San Juan River.

The suspended load of the San Juan River is 2.5 times larger than the bed-load. In order to estimate the bed-load contribution of each of the major basins drainging to the San Juan River (seven from Costa Rica and six from Nicaragua), and considering that for all those basins the SS loads have already been determined (Chapter 5), the bed-load for each basin was estimated as 40% of the suspended load. In addition, it was assumed that the Lake Nicaragua acts as a large-scale sediment trap for coarse sediment and, therefore, that it does not provide any bed-load sediment to the San Juan River.

A summary of the suspended, bed and total sediment loads, calculated for all the major basins draining from Costa Rica and Nicaragua to the San Juan River, is presented in Table 10.

Table 10. Total annual sediment load (including suspended and bed loads) produced by the Lake Nicaragua and the basin system draining to the San Juan River

Basin	Suspended sediment load (t yr^{-1})	Bed-load sediment load (t yr^{-1})	Total sediment load (t yr^{-1})
Major Costa Rican river basins draining directly to the San Juan River			
Frío River	269 000	108 000	377 000
Pocosol River	49 000	20 000	69 000
Infiernito River	78 000	31 000	109 000
San Carlos River	1 824 000	730 000	2 554 000
Cureña River	23 000	9 000	32 000
Sarapiquí River	458 000	183 000	641 000
Chirripó River	27 000	11 000	38 000
Major Nicaraguan river basins (including Lake Nicaragua) draining directly to the San Juan River			
Melchora River	278 000	111 000	389 000
Sábalos River	366 000	146 000	512 000
Santa Cruz River	244 000	98 000	342 000
Bartola River	23 000	9 000	32 000
Machado Creek	44 000	17 000	61 000
Las Banderas Creek	31 000	12 000	43 000
Lake Nicaragua	365 000	-	365 000
Summary for the whole San Juan - Colorado river system			
Total	4 079 000	1 485 000	5 556 000

The reason why the total sediment yield reported in Table 10 (5 566 000 t yr^{-1}) is lower than the total load measured in San Juan River (9 133 000 t yr^{-1}) is that the CALSITE model (Bradbury et al., 1993) used to determine the SS load produced by basins draining to the San Juan River, accounts only for sheet and rill erosion, leaving aside the sediment yield due to larger scale erosion processes (gullies and landslide). Application of the CALSITE model in the management of multiple hydropower operative plans and watershed management plans (Gómez-Delgado, 2002 and 2004; Gómez-Delgado et al., 2011; Marchamalo et al., 2007 and 2012), demonstrates the coherence and reliability of this model for determining the sheet/rill component from the total transported sediment yield. However, these multiple applications have also proved that a non-sheet/rill component is always present in tropical basins and must be accounted for in order to close a realistic sediment balance. In this context, according to Poesen et al. (2003), gullies and landslides may account for anything between 10% and 94% of total erosion in river basins.

In this particular case, the difference between the total amount of sediment measured in the San Juan River and the modelled sheet/rill sediment yield from all the basins (amounting to 3 567 000 t yr^{-1}) can be attributed to gullies and landslide erosion processes and this sediment yield was redistributed in proportion to the total

load reported for all the basins draining to the San Juan River and for Lake Nicaragua. The total (corrected) annual sediment loads by basin are reported in Table 11.

Table 11. Corrected annual loads for Lake Nicaragua and the basin system draining to San Juan River

Basin	Suspended sediment load (t yr^{-1})	Bed-load sediment load (t yr^{-1})	Total sediment load (t yr^{-1})
Major Costa Rican river basins draining directly to the San Juan River			
Frío River	433 000	185 000	618 000
Pocosol River	79 000	34 000	113 000
Infiernito River	126 000	54 000	180 000
San Carlos River	2 939 000	1 257 000	4 196 000
Cureña River	37 000	16 000	53 000
Sarapiquí River	738 000	316 000	1 054 000
Chirripó River	44 000	19 000	63 000
Major Nicaraguan river basins draining directly to the San Juan River			
Melchora River	448 000	192 000	640 000
Sábalos River	590 000	252 000	842 000
Santa Cruz River	393 000	168 000	561 000
Bartola River	37 000	16 000	53 000
Machado Creek	71 000	30 000	101 000
Las Banderas Creek	50 000	21 000	71 000
Lake Nicaragua	588 000	-	588 000
Summary for the whole San Juan - Colorado river system			
Colorado River	5 981 000	2 489 000	8 470 000
San Juan Bajo River	592 000	71 000	663 000

6.2. Estimation of the sediment load produced by Route 1856

Oreamuno and Villalobos (2013) established average erosion depths and annual erosion rates for the road bed, cut slopes, and fill slopes along Route 1856 by monitoring nine sites in the stretch of Route 1856 extending from Mojón II to the Infiernito River. These include the two largest rotational landslides, three gullies, the most intensively rilled cut slope (with 16 rills) and a sediment trap collecting sediment eroded by sheet erosion of the road bed and an adjacent cut slope. The selected sites include some of the most heavily eroded slopes in the study area and thus represent worst-case examples of erosion by land sliding, sheet erosion, rilling and gullying along the steepest part of Route 1856.

Mende & Astorga (2013) characterized, by means of intensive fieldwork, all the cut and fill slopes around Route 1856 along the entire stretch extending from Mojón II to Delta Costa Rica in terms of their geographic position, area, slope angle, type (land sliding, sheet erosion, rilling or gullying) and severity of erosion. Mende & Astorga also applied the erosion rates derived by Oreamuno and Villalobos to estimate sheet

and rill erosion for the cut and fill slopes. They grouped the result into five main sections along the Route, corresponding to the major river basins draining directly from Costa Rica to the San Juan – Colorado River system.

Based on sediment accumulation in a trap receiving runoff from a steeply sloping area of road bed (332 m^2) and cut slope (505 m^2) with a USLE LS factor of 2.32, Oreamuno and Villalobos found annual rates of land surface lowering due to sheet erosion to range between 0.061 and 0.095 $m^3\ m^{-2}\ yr^{-1}$ for dry and wet season conditions, respectively. The higher of these two rates was used here to estimate erosion of the road bed. This is doubly conservative because more than half of the land area draining to the sediment trap was actually very steep, cut slope formed in bare soil, and because wet season conditions are assumed to apply over the whole year. Hence, a constant average annual rate of land lowering due to sheet erosion equal to 0.095 $m^3\ m^{-2}\ yr^{-1}$ was selected and then adjusted according to the ratio between the USLES's LS topographic factor (Wischmeier and Smith, 1960) for the monitored plot and the LS factor for a typical section of road. The formulation used to calculate the LS factor is presented in equation (2) and was taken from McCool et al. (1993):

$$LS = \begin{cases} \left[\frac{L}{22.13}\right]^{1/2} (10.8 \sin\theta + 0.03) & \theta < 5.143° \\ \left[\frac{L}{22.13}\right]^{1/2} \left(\frac{\sin\theta}{\sin 5.143°}\right)^{0.6} & \theta \geq 5.143° \end{cases} \quad (2)$$

where L = length of slope (m) and θ = slope angle (degrees). Equation (3) presents the mathematical formulation for the reduction ratio ($Ratio_{LS}$) applied to the observed sheet erosion rate:

$$Ratio_{LS} = \frac{LS(L_{Road}, \theta_{Road})}{LS(L_{Slope}, \theta_{Slope})} \quad (3)$$

where $LS(A,\theta)$ = LS factor according to Eq.(2) corresponding to a plot of length of slope L and slope angle θ, in the area monitored boy Oreamuno and Villalobos.

The steepest section of route 1856 is the 7 km section between Mojón II and the mouth of the Infiernito River. For this section, a "road-plot" type of 1 m width by 100 m length and longitudinal slope of 10% was used, with the LS factor takink a value of 2.26. Longitudinal slopes are generally low along the remainder of Route 1856, and using a "road-plot" type of 1 m width by 16 m length, with cross slope of 3%, meant that the associated LS factor takes a value of 0.46. Therefore, the sheet erosion rate provider by Oreamuno and Villalobos was adjusted by a factor of 1.03 in the more steeply sloped section of Route 1856 and by a factor of 5.09 in the gently sloping, remainder of the road. The adjusted average annual rates of land lowering due to sheet erosion were multiplied by the area of each road-plot type, based on an average road bed width of 10 m, to calculate the average volume of eroded material.

To convert the volume into a mass, a volumetric bulk densitiy of 1.67 t m^{-3} was assumed. This value is widely used to represent the bulk density of silt-sand soils.

The total volumes and masses of sediment eroded annually from Route 1856 are summarized in Table 12 and plotted in Fig. 21. Road bed erosion estimates are based on the land surface lowering rates reported by Oreamuno and Villalobos, while cut and fill slope erosion is based on the findings of Mende and Astorga. Based on this exercise, the total volume of sediment eroded along Route 1856 during one year is estimated to be 60 780 m^3, which converts to 101 550 t.

Table 12. Potential sediment increments to the San Juan River sediment load due to construction of Route 1856 (basin discretized)

Basin	Road length (km)	Erosion volume (m^3)			Erosion load (t yr^{-1})		
		Road[a]	Slopes[b]	Total	Road	Slopes	Total
Major Costa Rican river basins draining directly to the San Juan River							
Infiernito River	38	12 260	28 000	40 260	20 450	46 750	67 250
S. Carlos River	11	2 060	600	2 660	3 450	1 000	4 450
Cureña River	28	5 220	7 560	12 780	8 700	12 650	21 350
Sarapiquí River	3	560	160	720	950	250	1 200
Chirripó River	22	4 100	260	4 360	6 850	450	7 300
Costa Rican area that drains directly to the San Juan River							
Total	102	24 200	36 580	60 780	40 400	61 100	101 550

[a]Oreamuno and Villalobos (2013) [b]Mende & Astorga (2013).

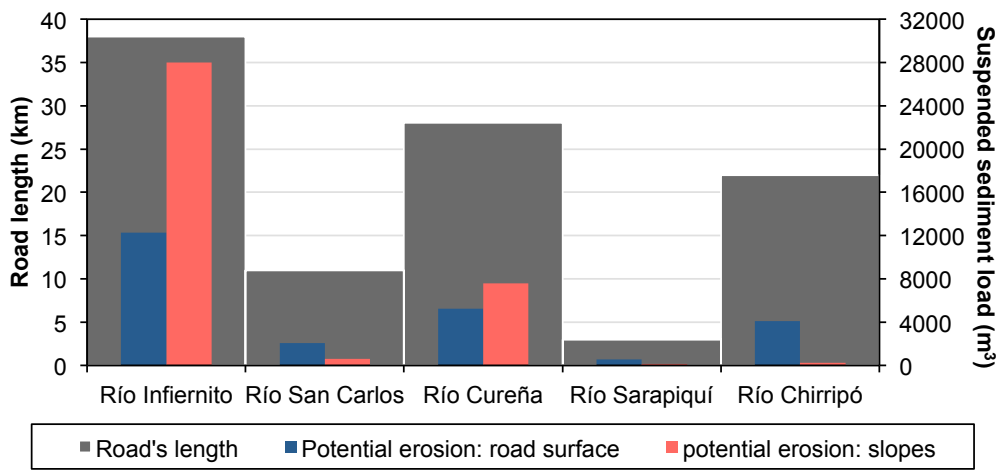


Figure 21. Potential erosion from the road bed and cut and fill slopes due to construction of Route 1856 (displayed by tributary basin, with the length of the road located in each basin indicated for context)

An average delivery ratio of 0.31 was calculated based on potential soil erosion and sediment yields estimated using the CALSITE model for major Costa Rican river basins draining directly to the San Juan River. However, this delivery ratio is related

to hydrological and sedimentological processes typical of large river systems with drainage basins of the order of 10 000 km^2. This delivery ratio is, therefore, inapplicable to the small drainage areas around Route 1856 (~ 3.5 km^2) due to scale differences. Recognising this, a much higher delivery ratio of 0.60 was selected, for use with respect to deliver of road-derived sediment to the San Juan River, based on the small size of the drainage areas and the particle size distributions of sediment eroded from Route 1856 reported by Oreamuno and Villalobos (2013). Inputs of road-derived sediment to the San Juan River based on a delivery ratio of 0.60 are shown in Table 13 and Fig. 22. According to these figures, the total volume of sediment delivered by Route 1856 to the San Juan River during one year is estimated to be 36 500 m^3, which converts to 60 800 t assuming a bulk density of 1.67 t m^{-3}.

Table 13. Sediment yield increments to the San Juan River sediment load due to construction of Route 1856 (basin discretized)

Basin	Road length (km)	Erosion volume (m^3)			Erosion load (t yr^{-1})		
		Road	Slopes	Total	Road	Slopes	Total
Major Costa Rican river basins draining directly to the San Juan River							
Infiernito River	38	7 360	16 800	24 160	12 250	28 050	40 300
S. Carlos River	11	1 240	360	1 600	2 050	600	2 650
Cureña River	28	3 140	4 540	7 680	5 200	7 600	12 800
Sarapiquí River	3	340	100	440	550	150	700
Chirripó River	22	2 460	160	2 620	4 100	250	4 350
Costa Rican area that drains directly to the San Juan River							
Total	102	14 540	21 960	36 500	24 150	36 650	60 800

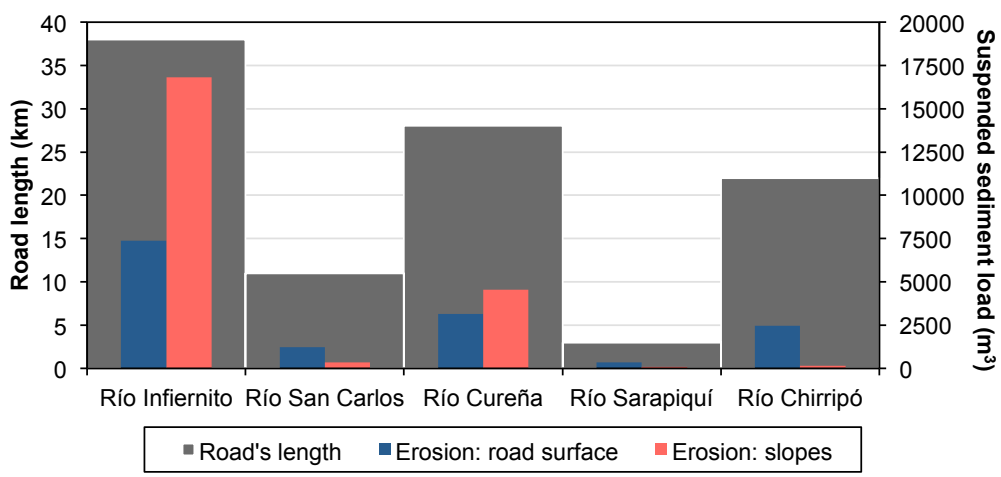


Figure 22. Sediment yields to the San Juan River due to construction of Route 1856 (displayed by tributary basin, with the length of road located in each basin indicated for context).

6.3. Sediment balance diagrams before and after construction of Route 1856

The total average annual sediment loads of all the basins draining to the San Juan River and for Lake Nicaragua reported in Table 11 corresponds to the period after construction of Route 1856. These results were used to create diagrams illustrating the pre- and post-Route 1856 sediment transport balances in the San Juan - Colorado River system (Figs. 23 and 24). The diagrams graphically display sediment inputs, fluxes and outputs, with the width of the mainstream and each of its tributary/distributary rivers scaled according to their average annual sediment loads. In these diagrams, sediment loads prior to construction of Route 1856 (illustrated in Fig. 23) were derived by subtracting from the post-construction sediment balance (illustrated in Fig. 24) the spatially-distributed, worst case scenario estimates of the inputs of sediment from Route 1856 that were derived and reported in Section 6.2.

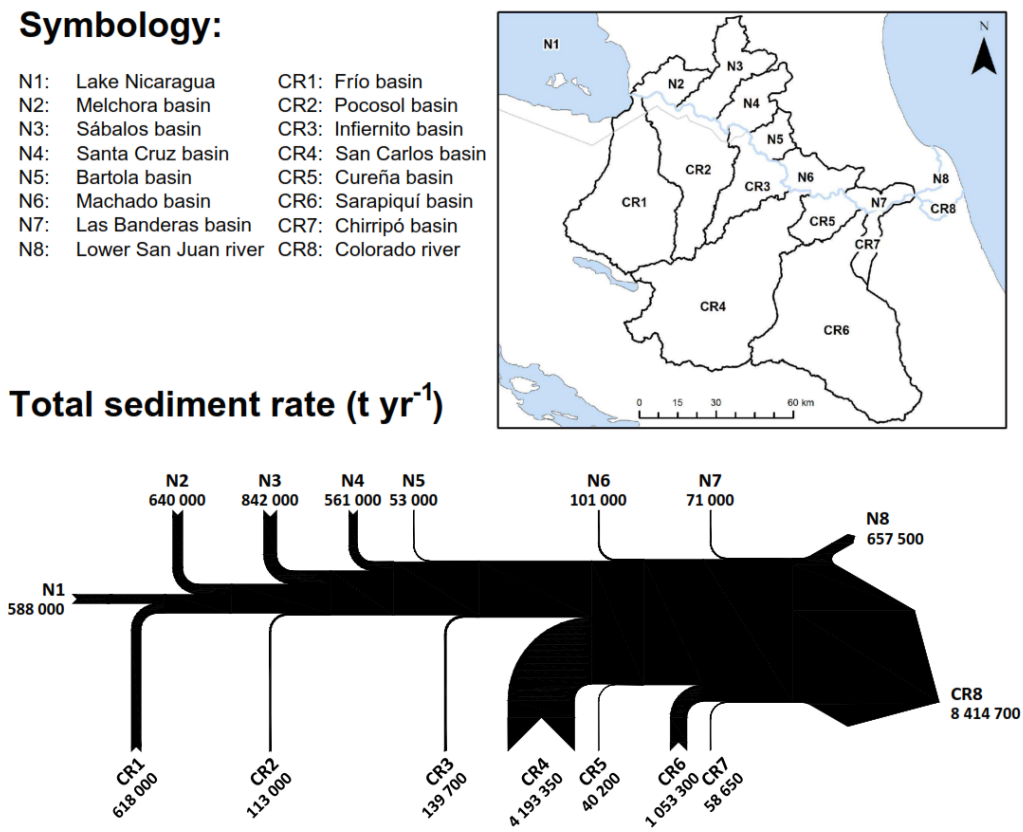


Figure 23. Average annual sediment balance prior to construction of Route 1856. This includes suspended and bed-loads from both Costa Rican and Nicaraguan basins. The widths of the inward arrows are proportional to the sediment load contributed by of each of the tributary river basins that confluence with the San Juan River between Mojón II and the lower San Juan – Colorado bifurcation at Delta Costa Rica.

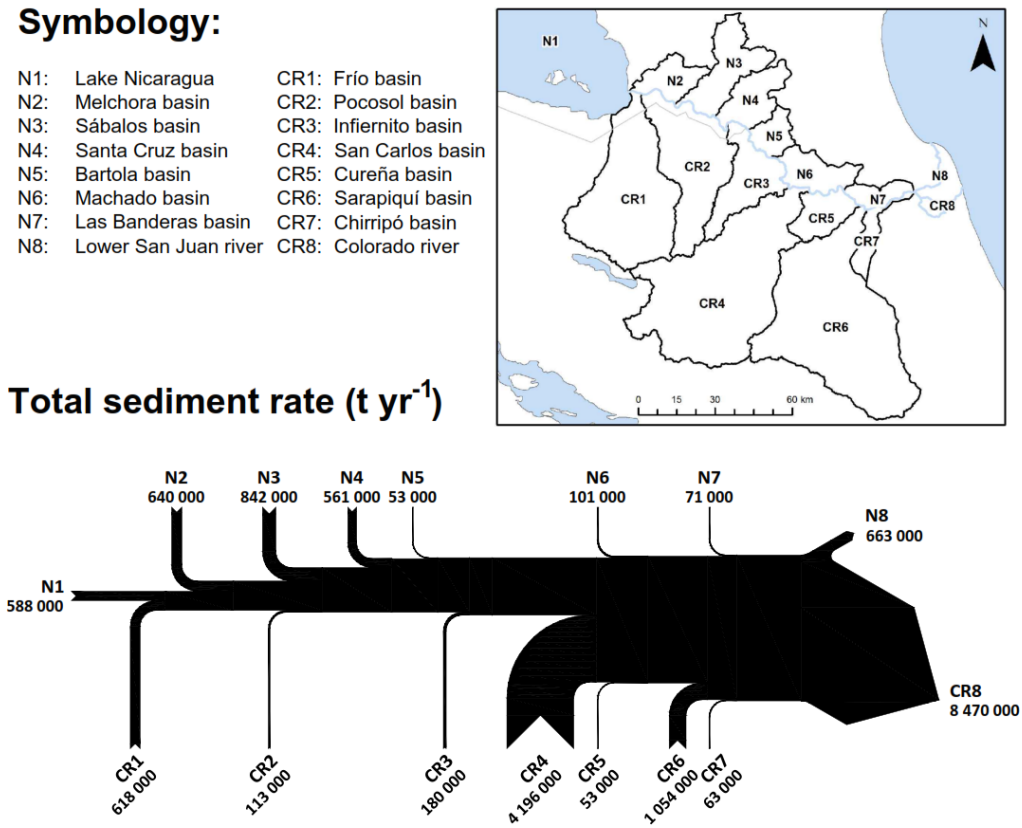


Figure 24. Average annual sediment balance post construction of Route 1856. This includes suspended and bed-loads input from both Costa Rican and Nicaraguan basins. The widths of the inward arrows are proportional to the sediment load contributed by of each of the tributary river basins that confluence with the San Juan River between Mojón II and the lower San Juan – Colorado bifurcation at Delta Costa Rica.

As at every step the disaggregated values of the suspended and bed sediment loads were calculated separately, additional sediment balances were plotted representing the individual balances for suspended, bed and total sediment loads, before and after construction of Route 1856. These diagrams are provided in APPENDIX I.

Finally, the two diagrams representing the sediment balance before and after the construction of Route 1856 (Figs. 23 and 24) were overlapped in order to illustrate the relative contribution of the additional sediment load attributable to construction of Route 1856. The resulting difference diagram is shown in Fig. 25.

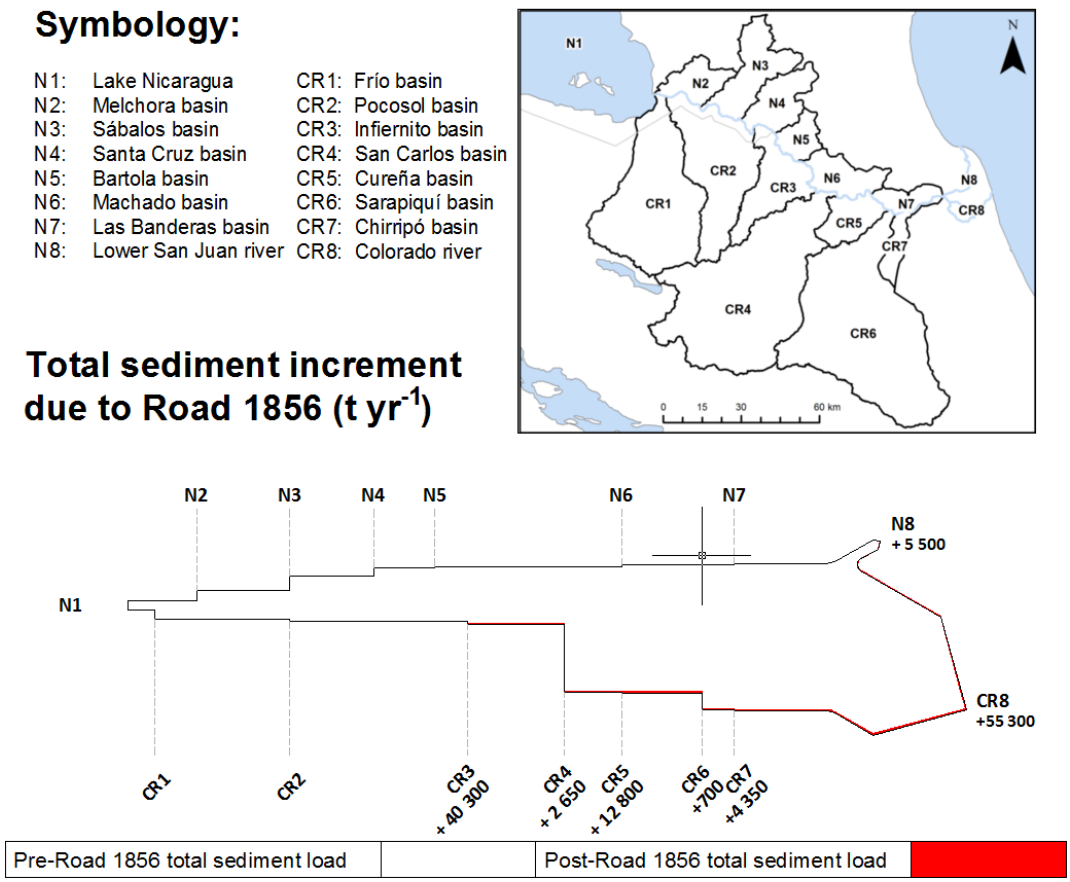


Figure 25. Increases in average annual sediment loads input to the San Juan – Colorado River system due to construction of Route 1856 are illustrated by the red lines in this version of the sediment balance diagram. Inputs of road-derived sediment are specified numerically: for example, the largest change in average annual sediment load input to the San Juan River is +40 300 t yr^{-1} from CR5 (the Infiernito Basin). The narrow width of the red band is correctly scaled and accurately portrays that cumulative sediment inputs from Route 1856 are so small relative to pre-construction loads that they are not only difficult to see but inconsequential and practically undetectable.

6.4. Silting process in the lower San Juan River

The pre- and post-Route 1856 sediment load diagram presented in Fig. 25 illustrates that the increase in the average annual sediment load input to the lower San Juan River is 5 500 t yr^{-1}. Assuming a bulk density of 1.67 t m^{-3}, this is equivalent to approximately 3 300 m^3 yr^{-1}. Consultation of recent satellite images indicates that the length of the Lower San Juan River is approximately 30 km, while examination of 40 available cross-sections of the river reveals that the average width of its channel is 92.2 m. Multiplying these two figures suggests that the area of the Lower San Juan River is approximately 2.77 km^2.

On the highly conservative assumption that all of the road-derived sediment input to the lower San Juan River by Route 1856 was to be deposited within the channel, this would raise the elevation of the bed by an average of 1.2 mm yr^{-1} – or the diameter of a single grain of medium-size sand. In considering the potential for even this rate of siltation, it should be remembered that this is an upper bound because conservative assumptions were made at each stage in estimating erosion, sediment delivery ratio and sediment yield from Route 1856. It follows that the potential change in the elevation of the bed of the lower San Juan River due to construction of Route 1856 is not only negligible but lies within the uncertainty band for any computation and is in any case inside the error range for measuring bed elevation, making any impact practically imperceptible.

7. CONCLUSIONS

A comprehensive hydrological and sedimentological study was made, integrating many different hydro-sedimentological measurements that have been performed from the beginning of the 1960s to the present day, both in Costa Rican basins draining to the San Juan River, and in the river itself.

From the existing data it must be concluded that there is no scientific evidence to prove any variation in the natural relationship between Discharge and Suspended Sediment (SS) Concentrations along the San Juan - Colorado River system due to construction of Route 1856, nor is there evidence of a change in the SS load regime in the San Juan River due to Route 1856. Neither is there scientific evidence to state that dry and rainy seasons present different Discharge - SS Concentration relationships.

Under the extreme assumption that after the construction of Route 1856, all the road and slope areas immediately become completely impermeable, the overall increase in the impermeable area for all the river basin systems (including major and minor basins) is 0.08%. Studying the effect of this change on the hydrological regime of eighty Costa Rican microbasins draining directly to the San Juan River, it was concluded, using two different methods and with a confidence level of 95%, that there is no scientific evidence of a change in the hydrological (discharge) regime of these microbasins, due to the construction of Route 1856. Additionally, after adding into the analysis of eighty microbasins, the seven major basins of Costa Rica that also drain to the San Juan River, it was demonstrated using scientifically sound methods that it is impossible to prove the existence of any changes in the hydrological regime of the basin system due to the construction of Route 1856. Beyond this, graphic comparison of pre- and post-Route 1856 discharge regimes showed that any possible hydrological effects attributed to the road that could be affecting the discharge regime of the Costa Rican basins are not even visible.

An advanced distributed model (CALSITE) was calibrated using available data and information on the actual sediment loads carried by several different Costa Rican rivers, allowing estimation of the SS loads produced by each of the Costa Rican and Nicaraguan basins draining to the San Juan River. Bed-load sediment inputs were also estimated based on the Einstein method, which is measurement-supported. Using modelled sediment yields, available records of measured SS loads and the estimated bed-loads, the current (post 2010) sediment balance for the entire river system was closed by correcting it to account for gully and landslide contributions.

The results of erosion monitoring and an inventory of all cut and fill slopes along Route 1856 between Mojón II and the lower San Juan – Colorado bifurcation at Delta Costa Rica were used together with application of the USLE and a conservative assumption concerning the sediment delivery ratio for small basins to estimate the increase in average annual sediment yield to the San Juan River that could be attributed to construction of Route 1856. The resulting average annual sediment yield of 36 500 m^3 yr^{-1} or 60 800 t yr^{-1} represents a 'worst case scenario' because conservative assumptions were made at each stage in its estimation. The yield of road-derived sediment was combined with the sediment balance to generate

illustrative diagrams for the total sediment balance in the San Juan – Colorado River system for pre- and post-Route 1856 conditions. These diagrams provide a simple, visual representation of how the contribution of road-derived sediment compares to the natural sediment load that San Juan and Lower San Juan Rivers transport in an average year. What Fig. 25 shows is that the contribution of Route 1856 is so small relative to pre-construction loads that it is practically undetectable.

In interpreting this analysis, it must also be remembered that all the figures quoted are averages, that they are subject to scientific uncertainty, and that the annual load is in any case itself naturally variable. It follows that the estimated input of road-derived sediment (60 800 t yr^{-1}) must be compared to uncertainty in the average annual load carried by the San Juan River. For example, the 95% confidence interval on the average annual load for suspended sediment is 5 181 000 to 7 966 000 t yr^{-1}, which is more than 50 times the estimated input of road-derived sediment.

Finally, it was demonstrated that even using conservative assumptions to make a 'worst case scenario' estimate of the annual yield of road-derived sediment and then assuming that all of the additional sediment supplied to the lower San Juan River would be deposited, the change in the elevation of the bed due to the construction of Route 1856 is not only negligible, but it also cannot be measured.

REFERENCES

Bradbury, P., Lea, N. & Bolton, P. (1993). *Estimating catchment sediment yield: Development of the GIS-based CALSITE model* (Project Report). Oxfordshire, United Kingdom: HR Wallingford.

Einstein, H.A. (1950). *The bed-load function for sediment transportation in open cannel flows* (Technical bulletin). Washington, United States: U.S. Department of Agriculture.

Gómez-Delgado, F. (2002). *Evaluation of the potential erosion and sediment yield in three basins of Costa Rica* (Grade thesis). University of Costa Rica, San José, Costa Rica. (in Spanish)

Gómez-Delgado, F. (2004). Report on the spatial distribution of the potential erosion and sediments production in the basin defined for the Peñas Blancas Hydroelectric Plant. Volume B1. ICE, San José, Costa Rica. (in Spanish)

Gómez-Delgado, F., Marchamalo-Sacristán, M. & Laporte-Molina, S. (2011). Calibrating a distributed model to estimate the sediment input rate to the Peñas Blancas reservoir in Costa Rica. In: J. D. Brea & F. Balocchi (Ed.), *Erosion - Sedimentation Processes in rivers and basins* (in Spanish). Technical Document No. 28. Montevideo, Uruguay: IHP-LAC, UNESCO.

Hawkins, R.H., Ward, T.J., Woodward, D.E. y Van Mullen, J.A. (2009). *Curve number hydrology – State of the practice*. United States of America: American Society of Civil Engineers.

Instituto Costarricense de Electricidad (1973) *Documentos de registro de la estación 690103 La Trinidad*. San José, Costa Rica: Author.

Instituto Costarricense de Electricidad (2010) *Criterio técnico sobre las eventuales implicaciones ambientales del desarrollo del Proyecto Hidroeléctrico Brito - San Isidro de la República de Nicaragua, sobre el territorio de Costa Rica*. San José, Costa Rica: Author.

Instituto Costarricense de Electricidad (2011) *Estimación de caudal en la estación 690103 La Trinidad*. San José, Costa Rica: Author.

INETER (2001) Boletín Hidrológico No. 2. Managua, Nicaragua. http://webserver2.ineter.gob.ni/Direcciones/Recursos%20Hidricos/boletin/edanterior/Bol22001/caudales.htm

INETER (2002) Boletín Hidrológico No. 4. Managua, Nicaragua. http://webserver2.ineter.gob.ni/Direcciones/Recursos%20Hidricos/boletin/edanterior/Bol42002/bol4pag4.htm

INETER (2006) Boletín Hidrológico No. 11. Managua, Nicaragua. http://webserver2.ineter.gob.ni/Direcciones/Recursos%20Hidricos/boletin/edanterior/Bol062006/bol06pag1.html

Leblois, E. & Sauquet, E. (2000). *Grid elevation models in hydrology – Part 1: Principles and a literature review; Part 2: HydroDem, User's manual*. Cemagref, Technical Notes, Lyon, France.

Marchamalo, M., Gómez-Delgado, F., Gonzalez, B. (2007). *Quantification of soil and water conservation potencial based on territorial analisys of the catchment. Birris basin case study* (in Spanish). Technical report. Turrialba, Costa Rica: CATIE-UICN

Marchamalo, M., Vignola, R., Gómez-Delgado, F. and González-Rodrigo, B. (2012) Quantifying Services and Identifying Watershed Priority Areas for Soil and Water Conservation Programs. In B. Rapidel, F. DeClerk, J.F. Le Coq J. Beer, *Ecosystem Services from Agriculture and Agroforestry, Measurement and Payment*. London, United Kindgdom: Earthscan.

McCool, D.K., George, G.O., Freckleton, M., Douglas, C.L. & Papemdick, R.I. (1993). Topographic effect on erosion from cropland in the Northwestern wheat region. Trans. ASAE 36 (s).

Mende, A. & Astorga, A. (2013). *Inventory of slopes and water courses related to the Border Road Nº 1856 between Mojón II and Delta Costa Rica.* San José, Costa Rica: Authors.

Oreamuno-Vega, R.A & Villalobos-Herrera, R. (2013). *Systematic Field monitoring of Erosion and Sediment Yield along Route 1856*. San José, Costa Rica: Centro de investigaciones en desarrollo sostenible CIEDES – Universidad de Costa Rica.

Poesen, J., Nachtergaele, J., Verstraeten, G. & Valentin, C. (2003). Gully erosion and environmental change: importance and research needs. *CATENA* 50, 91-133.

Wischmeier, W. H. & Smith, D.D. (1960). A universal soil-loss equation to guide conservation farm planning. *Transactions of the 7th International Congress Soil Science*. Brussels, Belgium.

APPENDIX A

SUSPENDED SEDIMENT RATING CURVES

MEAN MONTHLY SUSPENDED SEDIMENT LOAD

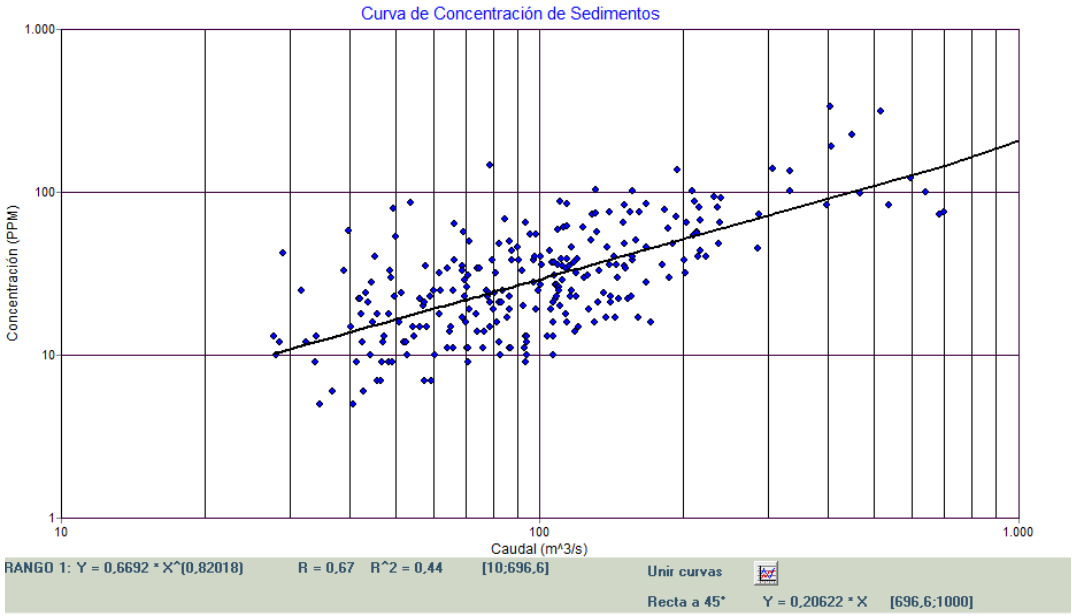
MEAN ANNUAL SUSPENDED SEDIMENT LOAD

Sediment stations:

12-03, 12-04, 12-05, 12-06, 12-11, 12-13, 14-02, 14-04, 14-05, 14-20, 16-02 & 16-05

Station 12-03 Puerto Viejo

Suspended sediment rating curve



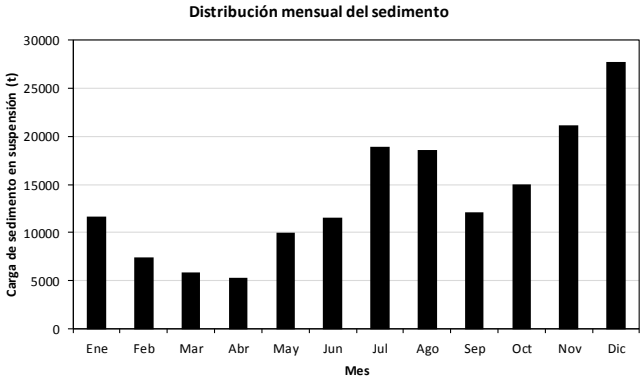
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 12 Sarapiquí
Estación 3 Puerto viejo

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 264
Periodo comprendido: 3/9/1970 hasta 2/7/1998

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	11694	97
Feb	7476	80
Mar	5887	68
Abr	5349	66
May	10030	95
Jun	11571	115
Jul	18861	145
Ago	18573	145
Sep	12133	119
Oct	15051	127
Nov	21122	145
Dic	27754	156
Total	**165507**	**113**



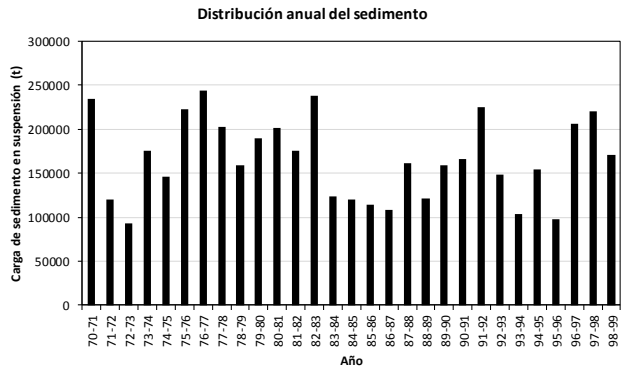
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 12 Sarapiquí
Estación 3 Puerto viejo

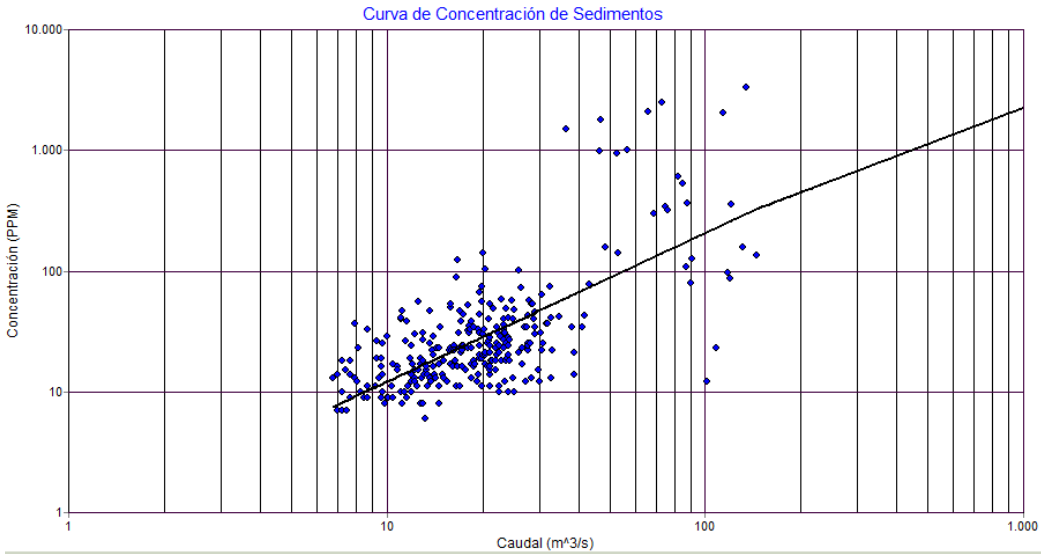
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 264
Periodo comprendido: 3/9/1970 hasta 2/7/1998

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
70-71	234408	158
71-72	120631	105
72-73	92570	86
73-74	175977	117
74-75	145769	106
75-76	223037	126
76-77	243577	137
77-78	202756	125
78-79	159076	114
79-80	189341	129
80-81	201006	130
81-82	176042	115
82-83	238041	134
83-84	123430	98
84-85	119953	99
85-86	114667	91
86-87	108464	95
87-88	160890	111
88-89	120804	100
89-90	158884	113
90-91	166336	116
91-92	224847	130
92-93	147813	109
93-94	103078	87
94-95	154481	104
95-96	97271	84
96-97	205561	133
97-98	220696	129
98-99	170323	119
Promedio	**165508**	**114**



Station 12-04 Veracruz

Suspended sediment rating curve



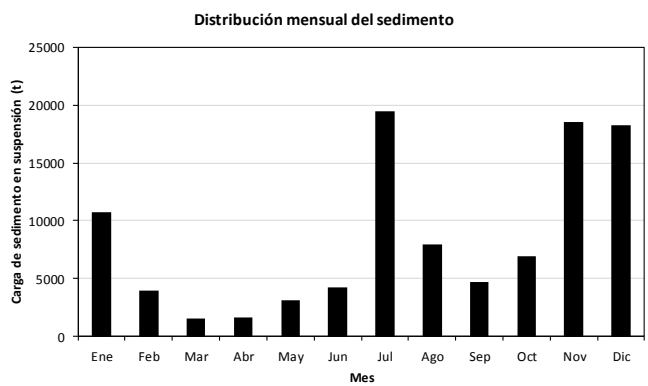
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 12 Sarapiquií
Estación 4 Veracruz

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 285
Periodo comprendido: 20/5/1972 hasta 21/11/2012

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	10712	28
Feb	3930	19
Mar	1559	15
Abr	1601	14
May	3129	19
Jun	4253	25
Jul	19481	32
Ago	7957	30
Sep	4703	28
Oct	6900	29
Nov	18515	39
Dic	18218	37
Total	**100963**	**26**



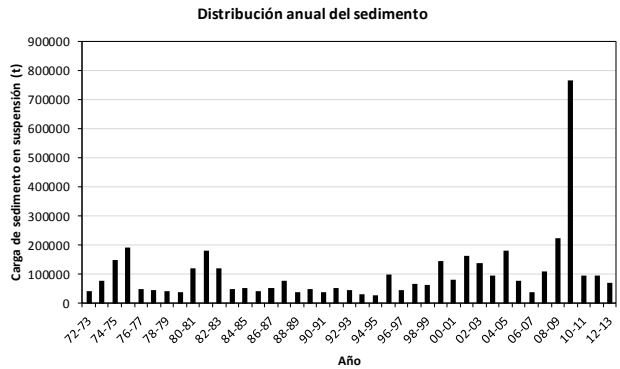
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 12 Sarapiquií
Estación 4 Veracruz

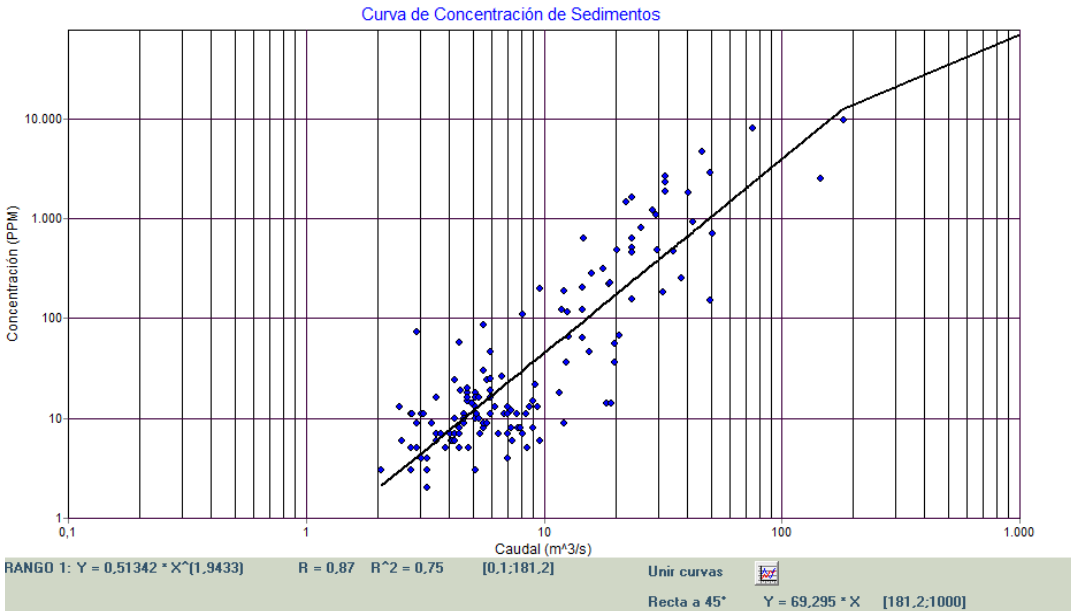
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 285
Periodo comprendido: 20/5/1972 hasta 21/11/2012

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
72-73	40870	23
73-74	77962	27
74-75	149836	29
75-76	192446	36
76-77	49434	23
77-78	45056	22
78-79	39687	21
79-80	38343	22
80-81	118947	32
81-82	180135	33
82-83	117903	27
83-84	49813	21
84-85	50687	24
85-86	40702	20
86-87	51858	23
87-88	78379	23
88-89	36374	22
89-90	47104	24
90-91	37947	22
91-92	52341	23
92-93	45820	23
93-94	31575	19
94-95	26732	18
95-96	97421	25
96-97	43442	24
97-98	66243	25
98-99	61921	25
99-00	144185	34
00-01	81910	28
01-02	161940	34
02-03	138578	31
03-04	94847	32
04-05	180686	36
05-06	77222	25
06-07	37360	20
07-08	107278	26
08-09	223069	39
09-10	765172	52
10-11	94483	29
11-12	95607	25
12-13	68147	26
Promedio	**100963**	**27**



Station 12-05 Bajos del Toro

Suspended sediment rating curve



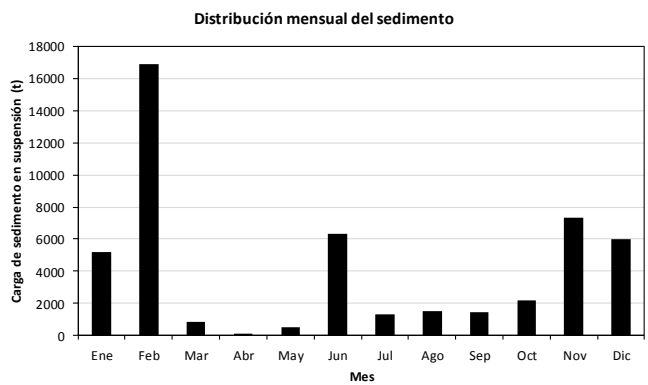
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 12 Sarapiquíí
Estación 5 Bajos del Toro

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 137
Periodo comprendido: 30/3/1985 hasta 12/12/2001

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	5181	5
Feb	16891	4
Mar	855	3
Abr	110	2
May	541	3
Jun	6329	5
Jul	1307	5
Ago	1526	6
Sep	1440	6
Oct	2220	6
Nov	7311	7
Dic	5970	6
Total	**49686**	**5**



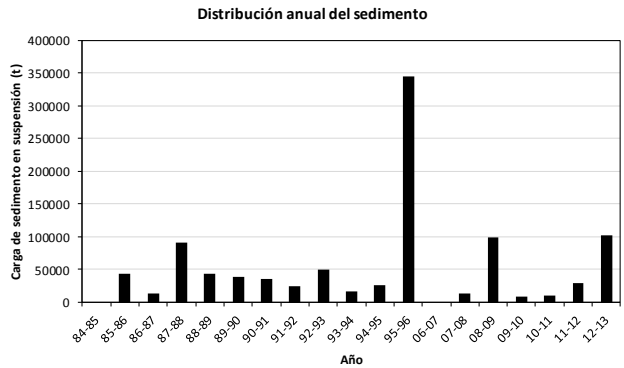
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 12 Sarapiquií
Estación 5 Bajos del Toro

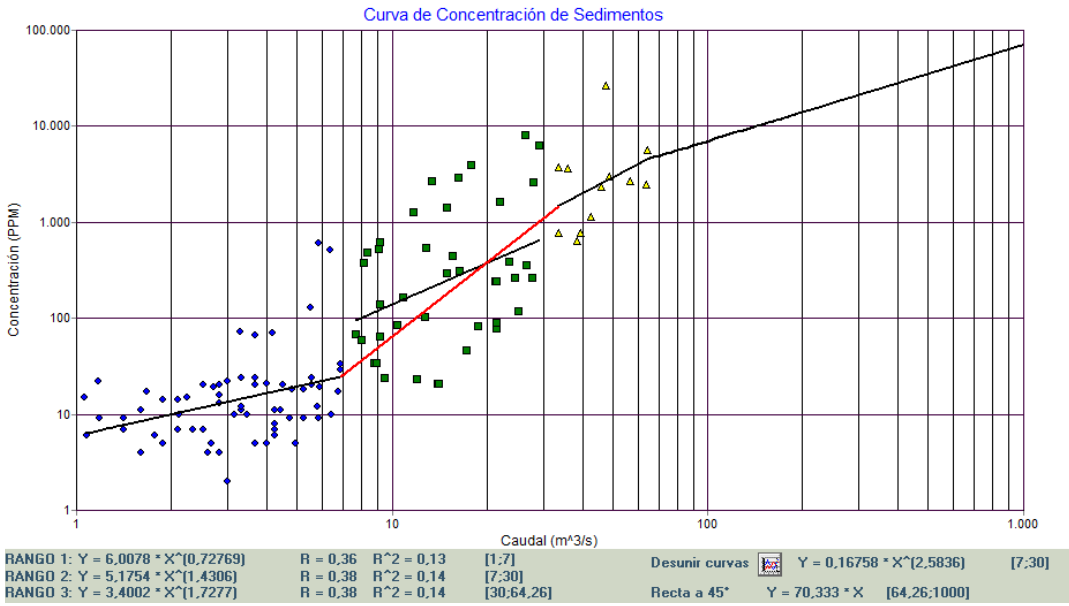
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 137
Periodo comprendido: 30/3/1985 hasta 12/12/2001

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
84-85	0	3
85-86	43305	7
86-87	14209	6
87-88	90750	7
88-89	43274	8
89-90	39381	7
90-91	35238	7
91-92	24795	6
92-93	50576	8
93-94	16758	6
94-95	26557	6
95-96	344493	7
06-07	0	1
07-08	12739	1
08-09	99342	4
09-10	8928	1
10-11	10945	1
11-12	29518	1
12-13	102834	1
Promedio	**49686**	**4**



Station 12-06 Toro

Suspended sediment rating curve



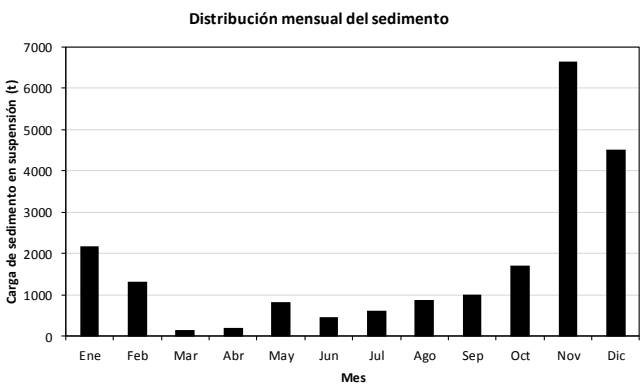
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 12 Sarapiquíí
Estación 6 Toro

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 117
Periodo comprendido: 18/1/1995 hasta 26/10/2010

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	2176	5
Feb	1328	4
Mar	143	2
Abr	194	2
May	833	3
Jun	452	4
Jul	623	4
Ago	878	4
Sep	1009	5
Oct	1710	6
Nov	6657	7
Dic	4513	7
Total	**20522**	**5**



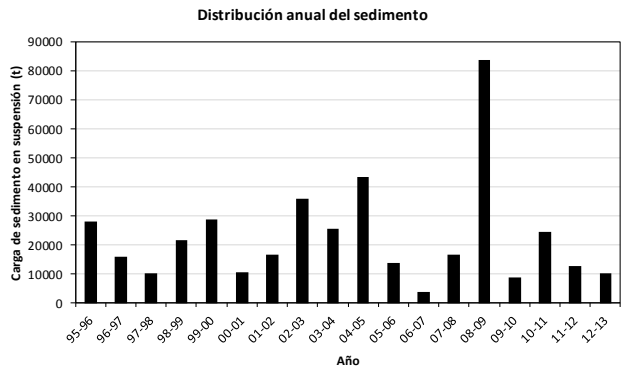
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 12 Sarapiquí
Estación 6 Toro

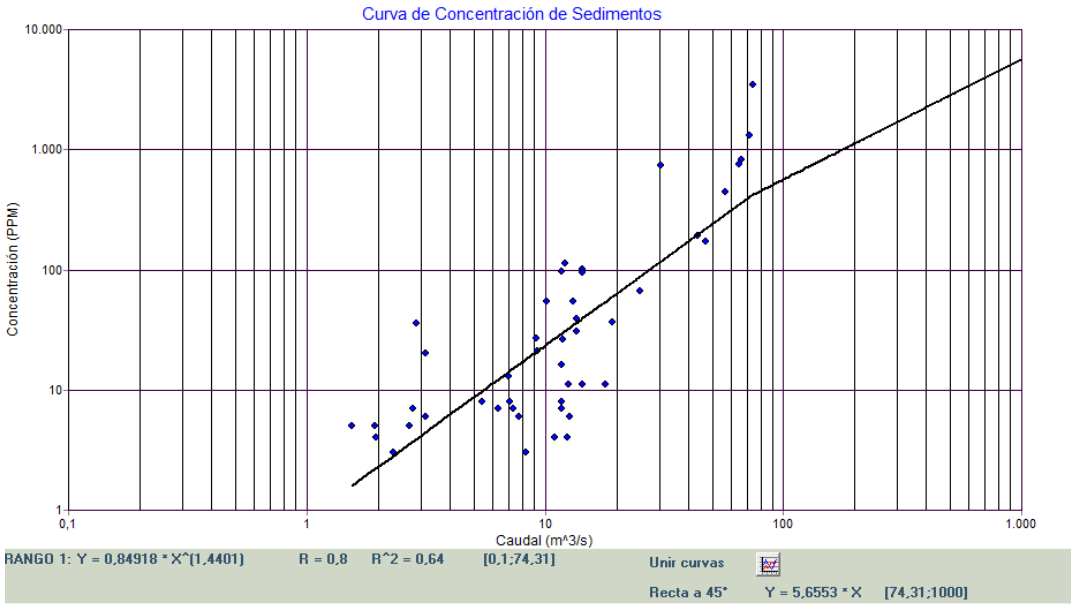
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 117
Periodo comprendido: 18/1/1995 hasta 26/10/2010

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
95-96	27859	4
96-97	15742	5
97-98	10212	4
98-99	21619	5
99-00	28846	5
00-01	10469	4
01-02	16666	4
02-03	35840	4
03-04	25585	6
04-05	43453	6
05-06	13864	4
06-07	3679	3
07-08	16648	4
08-09	83605	6
09-10	8683	4
10-11	24324	5
11-12	12587	4
12-13	10284	4
Promedio	**20522**	**4**



Station 12-11 San Miguel

Suspended sediment rating curve



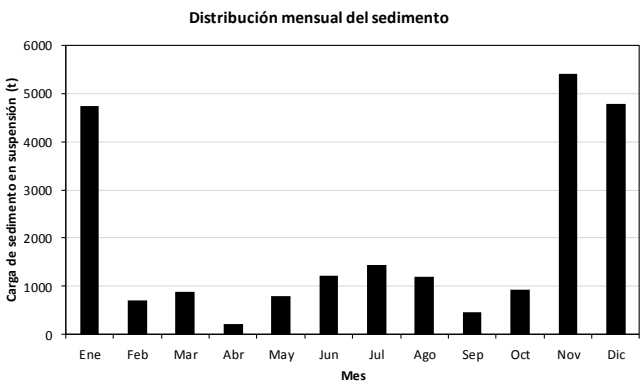
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 12 Sarapiquí
Estación 11 San Miguel

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 47
Periodo comprendido: 1/7/1998 hasta 12/1/2010

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	4745	15
Feb	714	8
Mar	886	7
Abr	210	5
May	799	9
Jun	1209	10
Jul	1440	12
Ago	1200	11
Sep	456	9
Oct	931	11
Nov	5402	19
Dic	4775	18
Total	**22773**	**11**



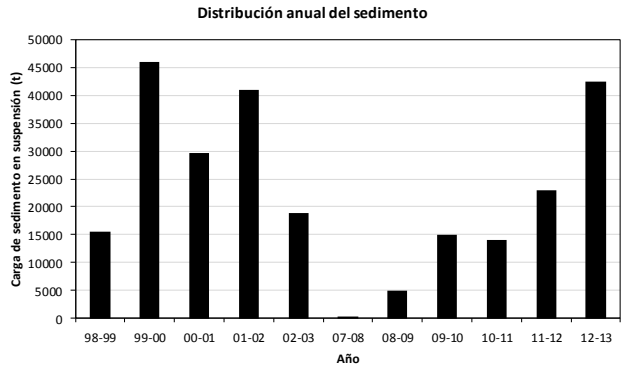
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 12 Sarapiquií
Estación 11 San Miguel

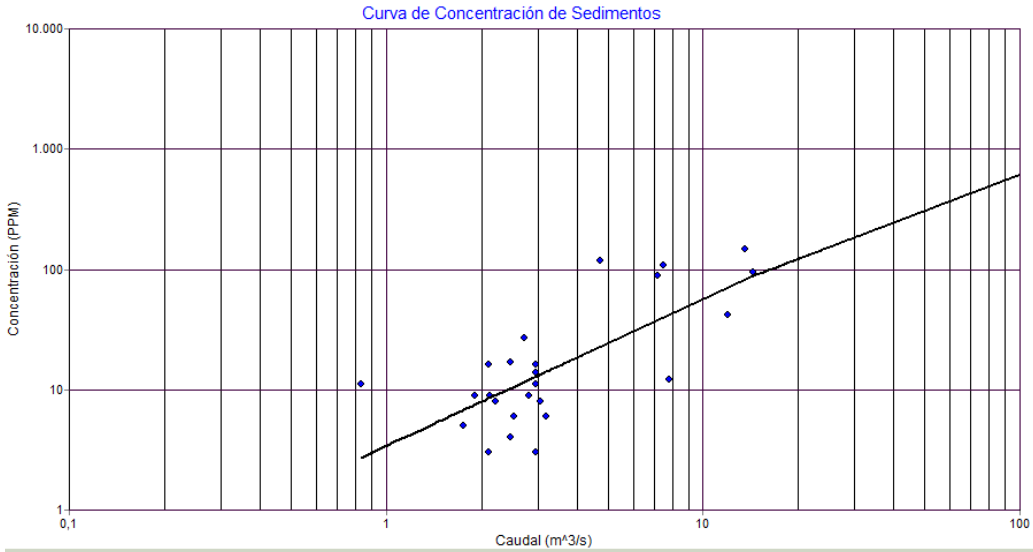
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 47
Periodo comprendido: 1/7/1998 hasta 12/1/2010

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
98-99	15456	10
99-00	45897	12
00-01	29632	12
01-02	40993	12
02-03	18920	13
07-08	304	6
08-09	5041	10
09-10	14898	11
10-11	13985	10
11-12	22926	9
12-13	42455	15
Promedio	**22773**	**11**



Station 12-13 Río Segundo

Suspended sediment rating curve



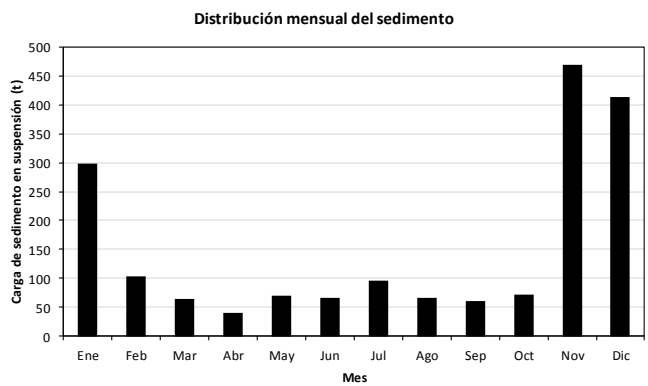
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 12 Sarapiquí
Estación 13 Río Segundo

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 25
Periodo comprendido: 3/6/1999 hasta 13/8/2009

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	298	4
Feb	104	2
Mar	64	2
Abr	41	2
May	70	2
Jun	67	2
Jul	96	3
Ago	66	2
Sep	61	2
Oct	72	2
Nov	470	5
Dic	413	4
Total	**1829**	**3**



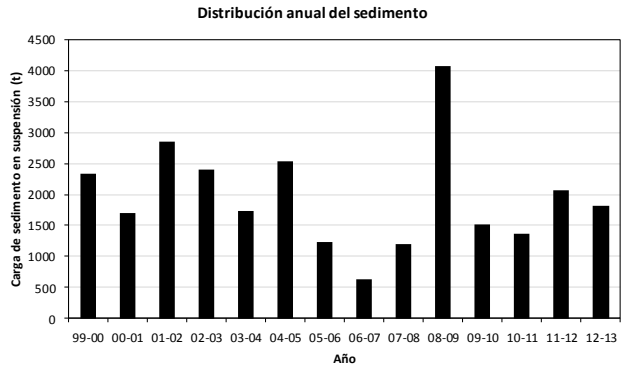
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 12 Sarapiquií
Estación 13 Río Segundo

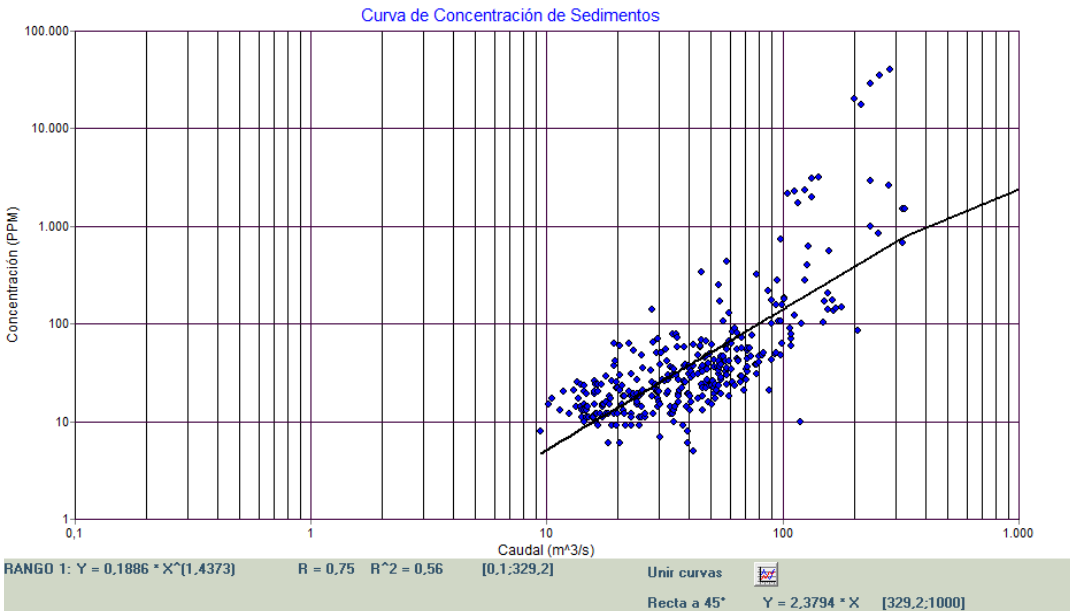
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 25
Periodo comprendido: 3/6/1999 hasta 13/8/2009

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
99-00	2332	3
00-01	1707	3
01-02	2846	3
02-03	2401	3
03-04	1725	3
04-05	2529	3
05-06	1230	2
06-07	626	2
07-08	1200	2
08-09	4065	3
09-10	1517	2
10-11	1364	2
11-12	2072	2
12-13	1813	2
Promedio	**1829**	**3**



Station 14-02 Jabillos

Suspended sediment rating curve



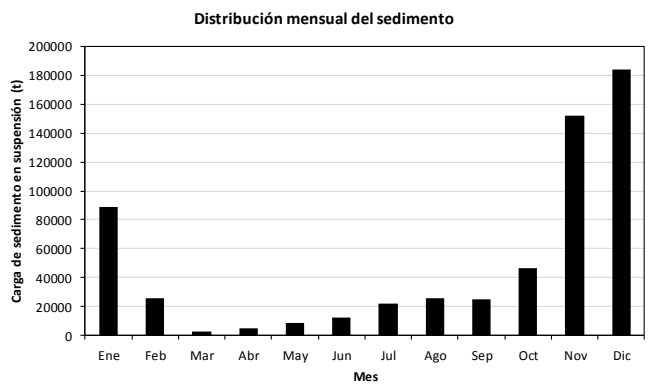
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 14 San Carlos
Estación 2 Jabillos

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 338
Periodo comprendido: 3/6/1967 hasta 13/1/2011

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	89058	47
Feb	25773	32
Mar	2439	23
Abr	5144	19
May	8530	28
Jun	12712	47
Jul	22199	60
Ago	25718	64
Sep	24752	67
Oct	46766	70
Nov	151673	79
Dic	184054	67
Total	**598823**	**50**



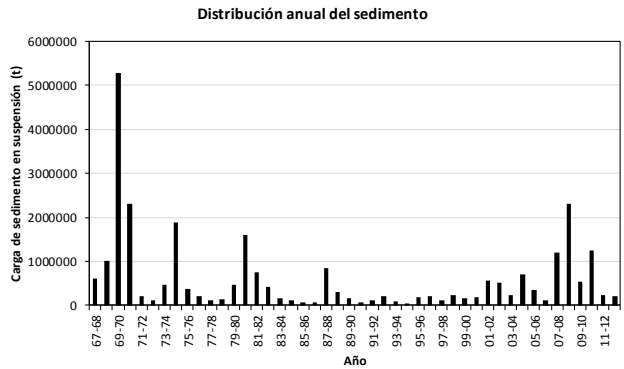
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 14 San Carlos
Estación 2 Jabillos

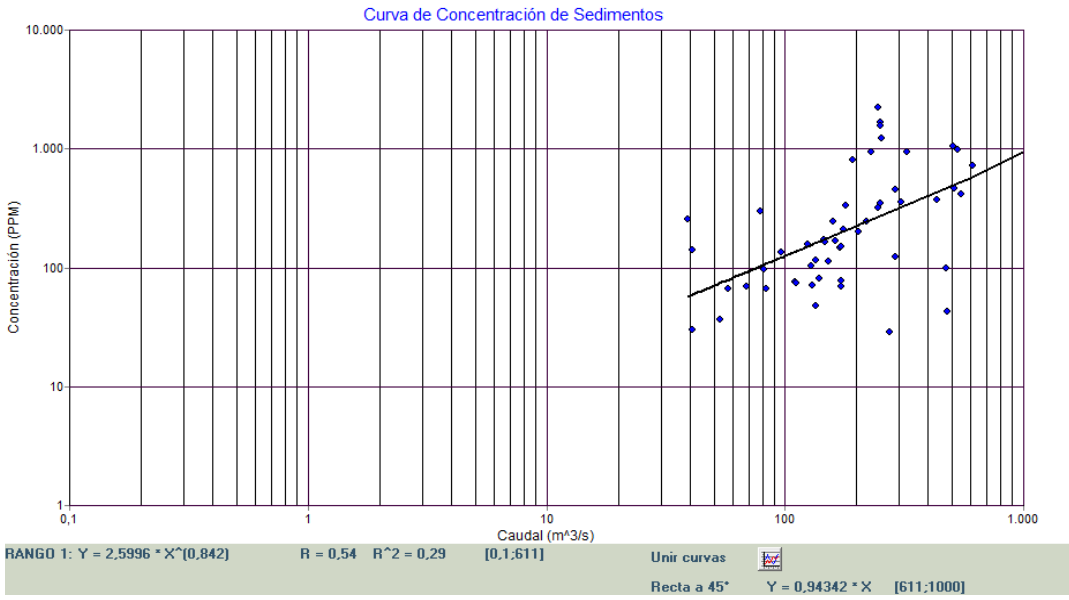
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 338
Periodo comprendido: 3/6/1967 hasta 13/1/2011

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
67-68	616130	67
68-69	1015699	62
69-70	5283115	82
70-71	2308064	84
71-72	208463	50
72-73	119209	42
73-74	468902	57
74-75	1871807	54
75-76	385737	49
76-77	217122	47
77-78	112533	39
78-79	133496	45
79-80	477245	47
80-81	1590355	60
81-82	750198	60
82-83	428370	50
83-84	153825	42
84-85	123983	42
85-86	74392	37
86-87	75879	38
87-88	835364	47
88-89	310685	47
89-90	156424	45
90-91	70127	38
91-92	117729	41
92-93	204789	40
93-94	91077	38
94-95	51059	32
95-96	186980	45
96-97	202424	52
97-98	107535	44
98-99	231787	46
99-00	151865	44
00-01	196634	51
01-02	557392	55
02-03	526224	53
03-04	228556	57
04-05	699629	63
05-06	360034	48
06-07	126925	44
07-08	1204812	59
08-09	2312645	79
09-10	531934	53
10-11	1235213	65
11-12	230574	39
12-13	202933	42
Promedio	**598823**	**50**



Station 14-04 Terrón Colorado

Suspended sediment rating curve



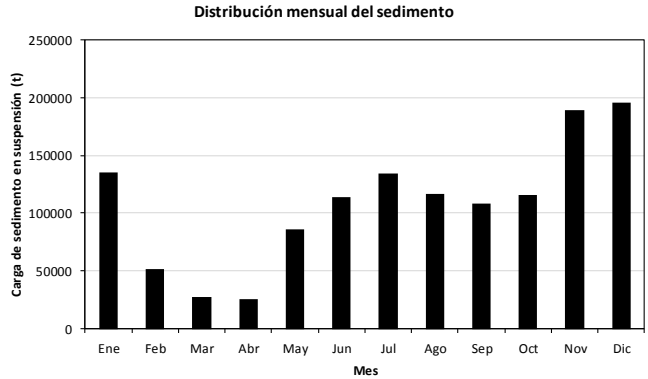
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 14 San Carlos
Estación 4 Terrón Colorado

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 53
Periodo comprendido: 7/10/1998 hasta 17/6/2009

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	135187	206
Feb	51437	129
Mar	27158	87
Abr	25720	83
May	85779	144
Jun	114141	188
Jul	134367	214
Ago	116668	196
Sep	108588	197
Oct	115710	200
Nov	189289	253
Dic	195570	237
Total	**1299620**	**178**



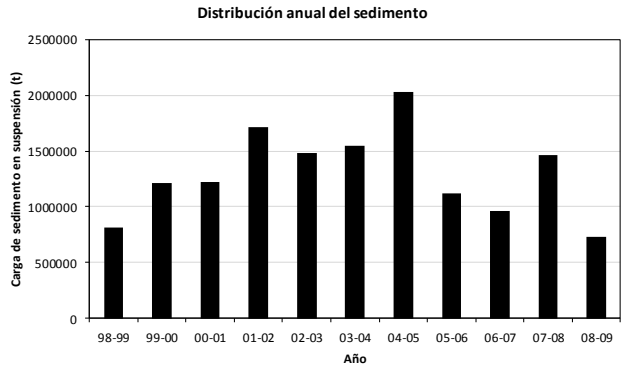
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 14 San Carlos
Estación 4 Terrón Colorado

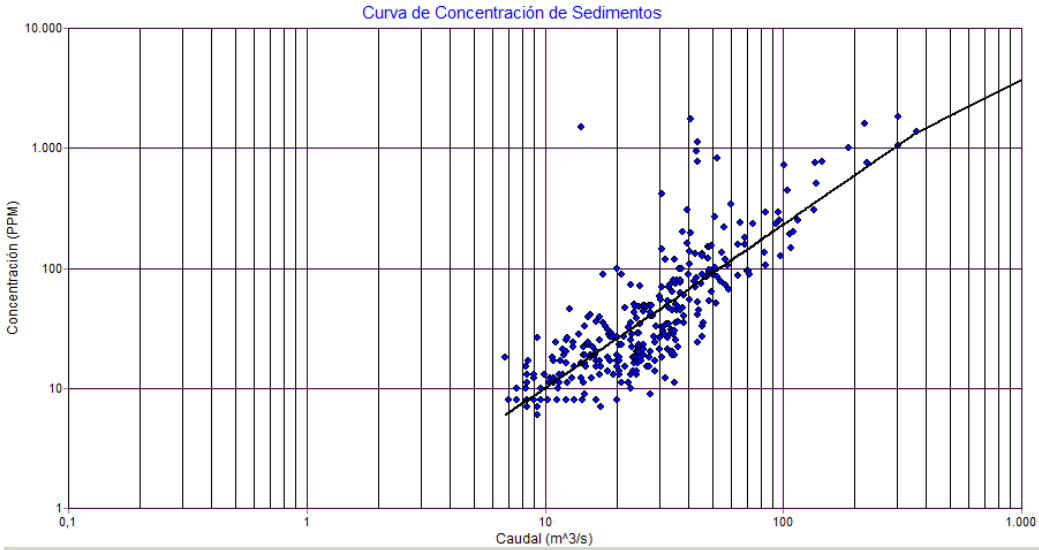
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 53
Periodo comprendido: 7/10/1998 hasta 17/6/2009

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
98-99	813368	167
99-00	1211918	161
00-01	1218509	166
01-02	1714428	187
02-03	1486594	173
03-04	1544806	193
04-05	2028312	213
05-06	1119198	153
06-07	961905	145
07-08	1462592	199
08-09	734184	213
Promedio	**1299619**	**179**



Station 14-05 Peñas Blancas

Suspended sediment rating curve



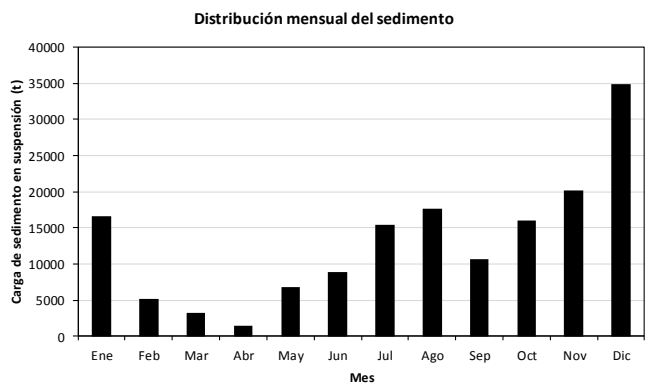
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 14 San Carlos
Estación 5 Peñas Blancas

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 311
Periodo comprendido: 16/5/1970 hasta 7/10/2011

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	16654	35
Feb	5222	25
Mar	3204	19
Abr	1447	14
May	6829	24
Jun	8875	33
Jul	15414	44
Ago	17644	44
Sep	10662	40
Oct	15927	44
Nov	20175	47
Dic	34855	48
Total	**156913**	**35**



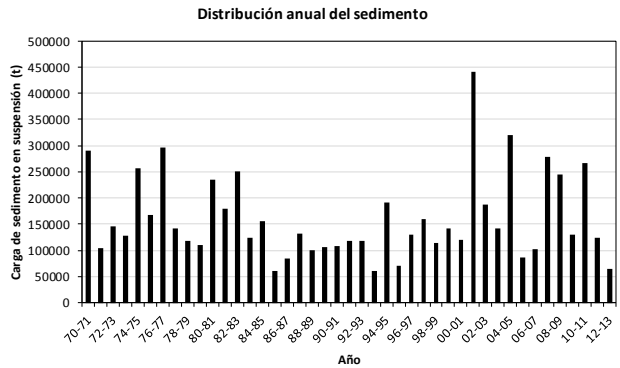
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 14 San Carlos
Estación 5 Peñas Blancas

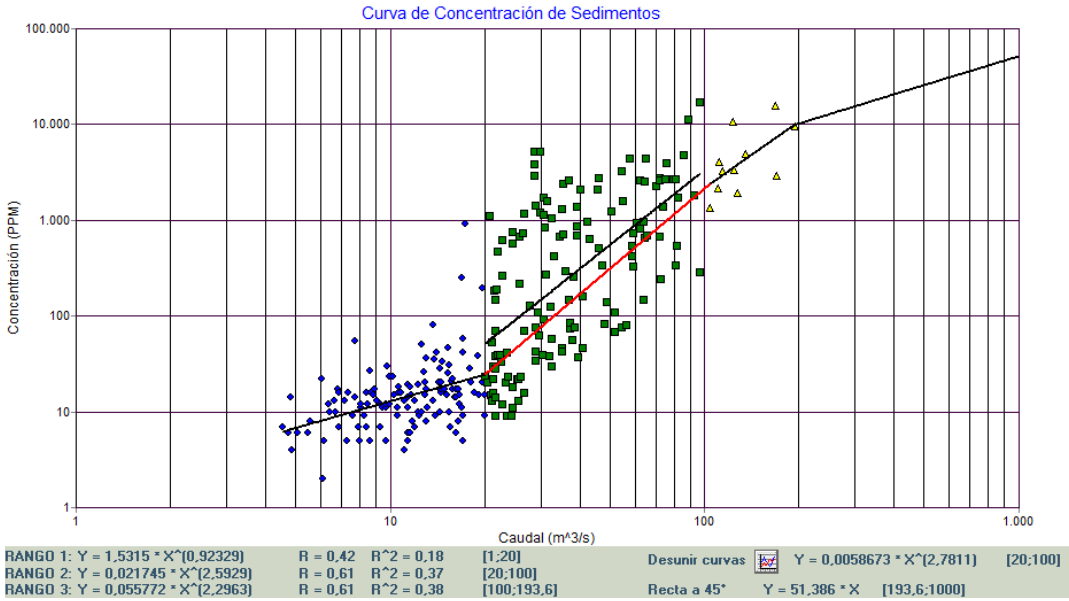
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 311
Periodo comprendido: 16/5/1970 hasta 7/10/2011

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
70-71	290658	51
71-72	104112	32
72-73	145208	37
73-74	127335	35
74-75	256882	36
75-76	167037	34
76-77	296474	41
77-78	142675	36
78-79	117350	32
79-80	109417	33
80-81	234097	40
81-82	179599	36
82-83	250163	39
83-84	124303	31
84-85	155343	35
85-86	60047	25
86-87	83526	29
87-88	132790	33
88-89	100262	31
89-90	106514	34
90-91	108187	33
91-92	118663	34
92-93	118048	31
93-94	59954	25
94-95	191928	30
95-96	70393	28
96-97	130684	35
97-98	158647	34
98-99	113892	32
99-00	141428	35
00-01	119728	36
01-02	441574	44
02-03	186499	38
03-04	141442	39
04-05	320183	47
05-06	87094	27
06-07	102228	29
07-08	278406	35
08-09	245858	42
09-10	130313	35
10-11	266360	36
11-12	123229	32
12-13	65387	25
Promedio	**156913**	**34**



Station 14-20 Pocosol

Suspended sediment rating curve



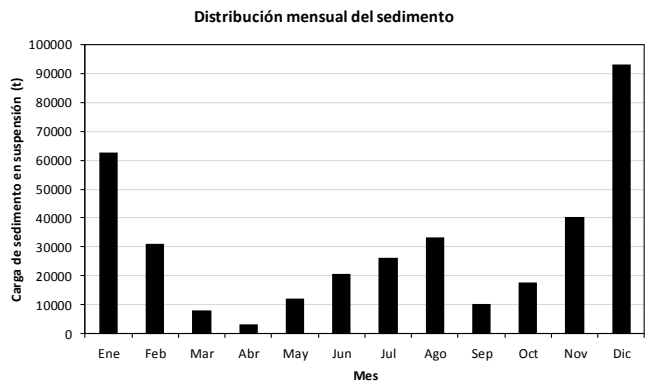
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 14 San Carlos
Estación 20 Pocosol

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 278
Periodo comprendido: 26/6/1980 hasta 12/6/2012

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	62611	20
Feb	31267	15
Mar	8111	11
Abr	3169	9
May	12116	14
Jun	20523	17
Jul	26095	22
Ago	33166	22
Sep	10332	19
Oct	17631	20
Nov	40222	24
Dic	92918	26
Total	**358167**	**18**



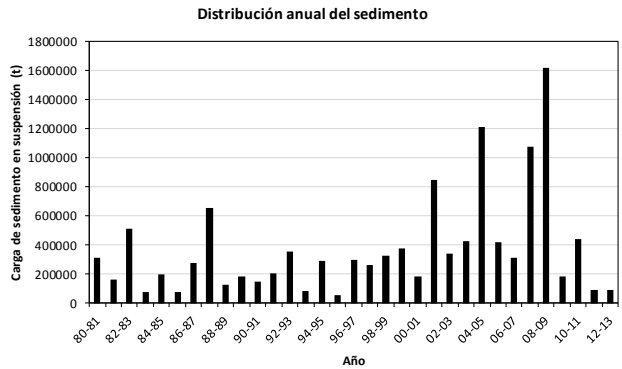
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 14 San Carlos
Estación 20 Pocosol

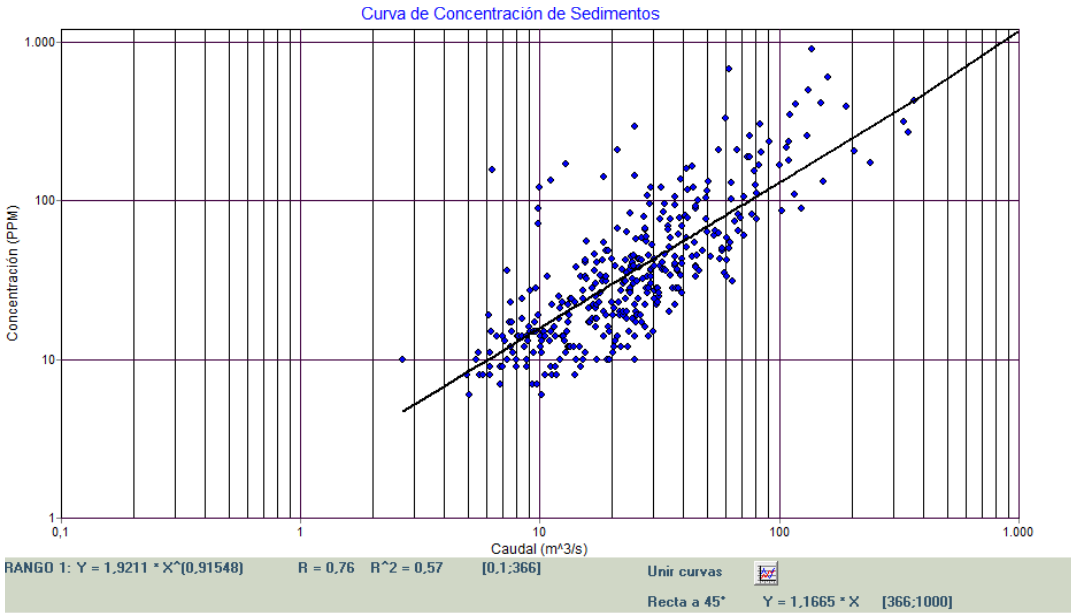
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 278
Periodo comprendido: 26/6/1980 hasta 12/6/2012

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
80-81	313027	22
81-82	159535	16
82-83	511584	19
83-84	77552	15
84-85	195022	18
85-86	76084	14
86-87	274232	22
87-88	653666	24
88-89	122636	15
89-90	185292	20
90-91	145057	16
91-92	202426	19
92-93	354275	17
93-94	81885	14
94-95	286548	16
95-96	56400	15
96-97	293749	21
97-98	260690	19
98-99	325477	19
99-00	374098	19
00-01	182818	20
01-02	848782	22
02-03	339358	21
03-04	422327	22
04-05	1209970	26
05-06	418707	16
06-07	310625	18
07-08	1076581	20
08-09	1617471	29
09-10	184318	18
10-11	442155	8
11-12	88132	5
12-13	87117	6
Promedio	**358167**	**17**



Station 16-02 Guatuso

Suspended sediment rating curve



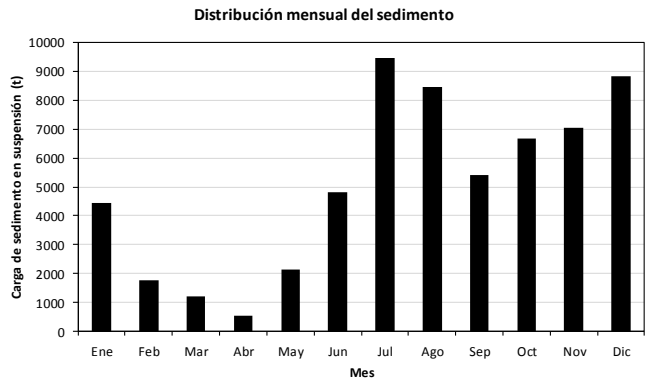
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 16 Frío
Estación 2 Guatuso

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 367
Periodo comprendido: 12/1/1970 hasta 4/7/2012

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	4435	27
Feb	1765	18
Mar	1202	13
Abr	562	10
May	2146	16
Jun	4822	29
Jul	9472	43
Ago	8438	41
Sep	5393	33
Oct	6685	36
Nov	7055	37
Dic	8830	38
Total	**60806**	**28**



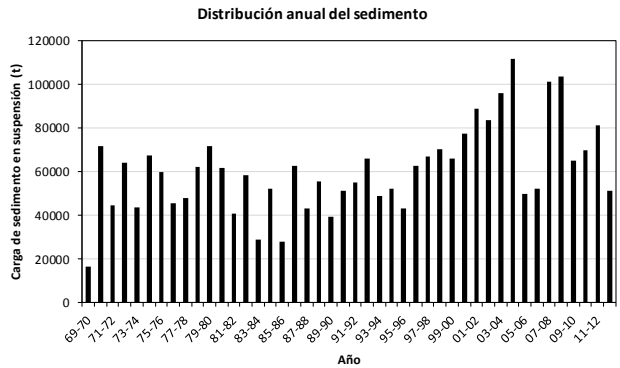
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 16 Frío
Estación 2 Guatuso

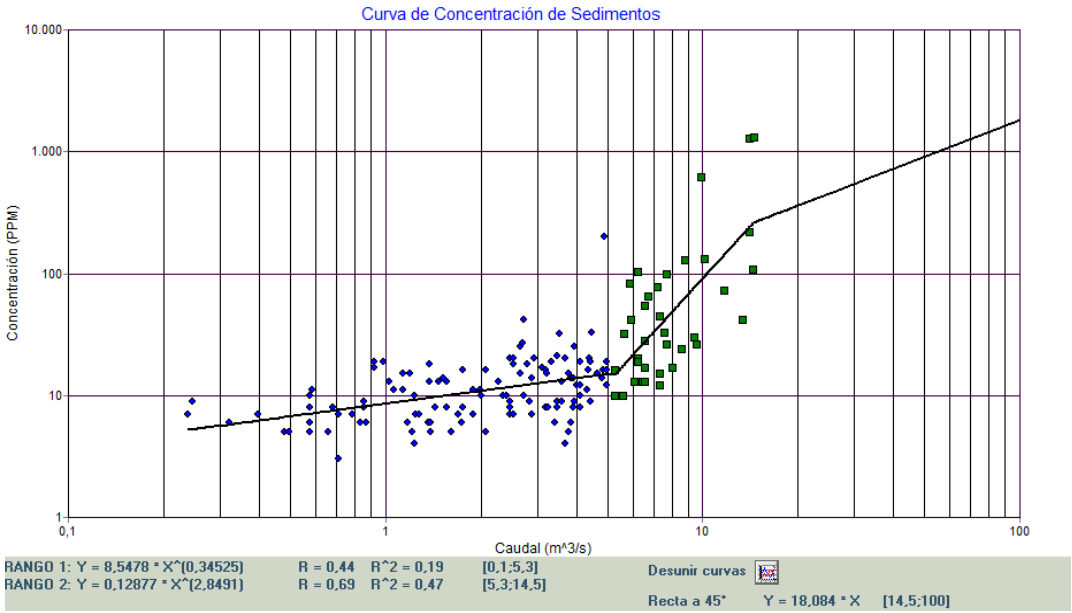
Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 367
Periodo comprendido: 12/1/1970 hasta 4/7/2012

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
69-70	16236	31
70-71	71851	34
71-72	44505	25
72-73	64070	30
73-74	43699	26
74-75	67458	28
75-76	59628	27
76-77	45541	26
77-78	48025	25
78-79	62214	29
79-80	71481	30
80-81	61661	31
81-82	40723	25
82-83	58405	27
83-84	28748	20
84-85	51927	27
85-86	27825	20
86-87	62535	28
87-88	43039	24
88-89	55462	27
89-90	39488	23
90-91	51045	24
91-92	54758	27
92-93	66142	28
93-94	48830	25
94-95	51894	25
95-96	43141	24
96-97	62661	31
97-98	66784	27
98-99	70259	30
99-00	65739	31
00-01	77523	35
01-02	88779	32
02-03	83577	32
03-04	95682	36
04-05	111367	40
05-06	49533	26
06-07	51998	24
07-08	100959	34
08-09	103435	38
09-10	64819	28
10-11	69750	30
11-12	81131	32
12-13	51139	32
Promedio	**60806**	**29**



Station 16-05 Santa Lucía

Suspended sediment rating curve



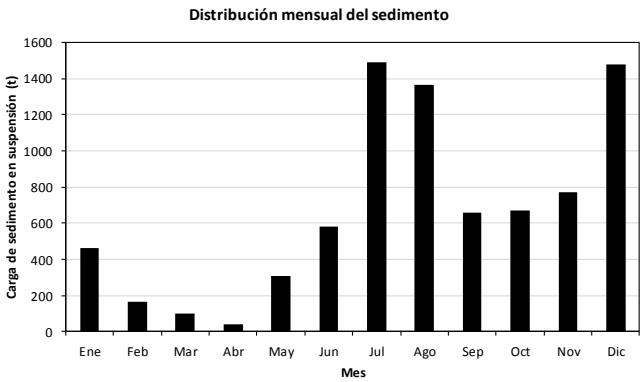
Mean monthly suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE MENSUAL DE SEDIMENTOS

Cuenca 16 Frío
Estación 5 Santa Lucía

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 153
Periodo comprendido: 23/6/1984 hasta 6/1/2011

Mes	Carga (t)	Q ($m^3 s^{-1}$)
Ene	462	4
Feb	166	2
Mar	99	2
Abr	38	1
May	308	2
Jun	581	4
Jul	1490	6
Ago	1365	6
Sep	656	5
Oct	670	5
Nov	769	5
Dic	1476	5
Total	**8079**	**4**



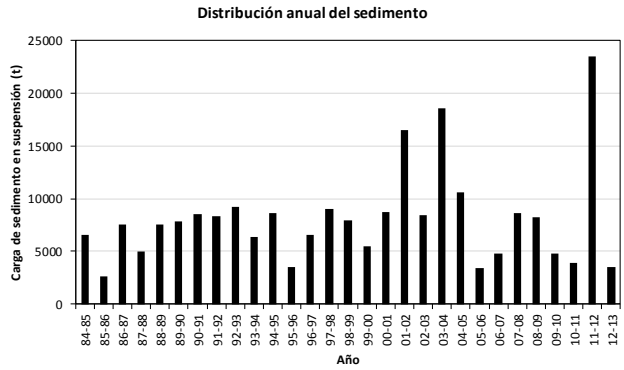
Mean annual suspended sediment load

INSTITUTO COSTARRICENSE DE ELECTRICIDAD
CENTRO DE SERVICIOS ESTUDIOS BÁSICOS DE INGENIERÍA - ÁREA DE HIDROLOGÍA
TONELAJE ANUAL DE SEDIMENTOS

Cuenca 16 Frío
Estación 5 Santa Lucía

Número de muestras utilizadas en la confección de la curva de descarga de sedimentos: 153
Periodo comprendido: 23/6/1984 hasta 6/1/2011

Año hidro.	Carga (t)	Q ($m^3 s^{-1}$)
84-85	6530	4
85-86	2618	3
86-87	7596	4
87-88	4963	4
88-89	7526	4
89-90	7881	4
90-91	8502	4
91-92	8352	4
92-93	9212	4
93-94	6335	3
94-95	8667	4
95-96	3504	3
96-97	6567	4
97-98	8976	4
98-99	7964	4
99-00	5505	4
00-01	8696	4
01-02	16480	5
02-03	8473	4
03-04	18505	5
04-05	10628	5
05-06	3387	3
06-07	4801	3
07-08	8673	4
08-09	8285	5
09-10	4764	4
10-11	3938	3
11-12	23425	6
12-13	3546	4
Promedio	**8079**	**4**



APPENDIX B

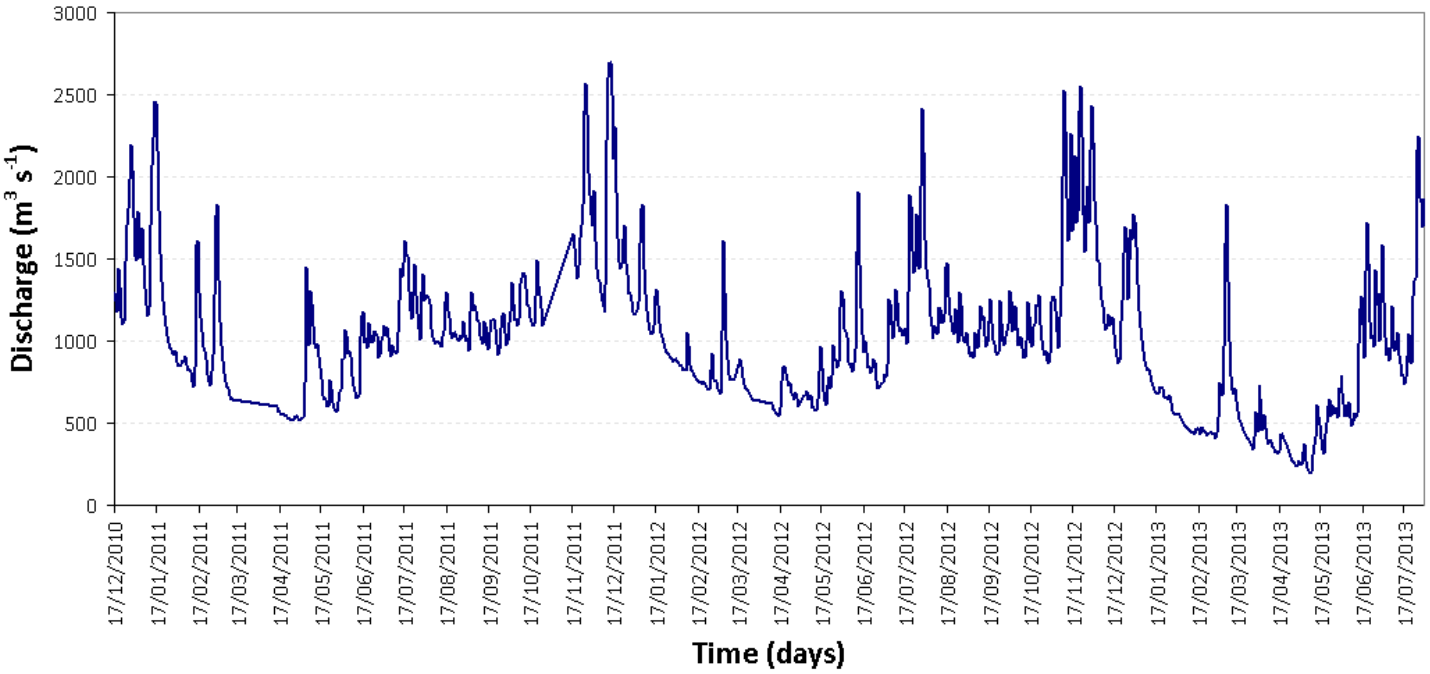
MONTHLY DISCHARGE MEASUREMENTS BY DOPPLER DEVICE AT DELTA COLORADO (11-04) GAUGING STATION

Table B.1 Monthly discharge measurements (using Doppler device) at Delta Colorado (11-04) station

Date	Time	Water stage (m)	Discharge ($m^3 s^{-1}$)
13/12/2010	14:35	1.59	1430
14/12/2010	09:13	1.96	1650
15/12/2010	10:45	1.74	1490
15/12/2010	15:29	1.63	1440
16/12/2010	10:37	1.49	1350
18/01/2011	16:35	2.04	1720
19/01/2011	09:42	1.75	1540
20/01/2011	09:21	1.32	1360
01/03/2011	15:40	2.09	1660
02/03/2011	09:31	2.36	1980
03/03/2011	12:16	1.47	1360
05/04/2011	09:50	0.25	627
27/04/2011	13:23	0.99	533
01/06/2011	12:29	1.58	817
21/06/2011	09:29	2.07	1120
06/07/2011	15:59	1.72	861
30/07/2011	10:00	2.57	1370
30/08/2011	10:31	1.90	991
22/02/2012	10:46	1.38	685
29/03/2012	10:41	1.23	702
27/06/2012	12:39	1.35	636
01/08/2012	10:45	2.53	1,360
29/08/2012	10:37	1.83	923
14/11/2012	10:13	2.91	1,650
19/12/2012	9:57	1.68	786
30/01/2013	10:46	1.11	587
06/03/2013	10:51	1.26	668
23/04/2013	10:08	0.70	424
29/05/2013	09:53	2.35	576
26/06/2013	09:18	3.26	1600

APPENDIX C

DAILY DISCHARGE AT DELTA COLORADO (11-04) GAUGING STATION FOR THE PERIOD DECEMBER 2010 - JULY 2013



APPENDIX D

SUSPENDED SEDIMENT (SS) SAMPLES TAKEN AT LA TRINIDAD (01-03, JAN 1974 - MAR 1976) AND DELTA COLORADO (11-04, DEC 2010 - JUN 2013) GAUGING STATIONS

Table D.1 Suspended sediment and discharge sampling at La Trinidad (01-03) station

Date	Time	Water stage (m)	Discharge ($m^3 s^{-1}$)	Sediment concentration (mg l^{-1})
09/01/1974	-	1,8	955	177
04/06/1974	-	1,61	861	146
06/11/1974	-	2,34	1230	99
07/12/1974	-	5,52	3100	621
14/01/1975	-	1,42	745	70
05/03/1975	-	1	571	38
25/03/1975	-	0,86	514	38
20/08/1975	-	3,17	1690	203
23/09/1975	-	2,78	1549	213
20/11/1975	-	2,95	1570	176
30/01/1976	-	1,93	979	73
17/03/1976	-	1,28	708	40

Table D.2 Sediment and discharge samplig at Delta Colorado (11-04) station

Date	Time	Water stage (m)	Discharge ($m^3 s^{-1}$)	Sediment concentration (mg l^{-1})
13/12/2010	15:43	1,59	1430	360
16/12/2010	10:05	1,51	1350	227
01/03/2011	16:10	2,07	1660	213
02/03/2011	09:50	2,38	1949	321
02/03/2011	09:59	2,35	1980	262
03/03/2011	13:26	1,46	1356	126
03/03/2011	13:32	1,43	1338	121
05/04/2011	12:26	0,25	627	148
01/06/2011	13:01	1,58	817	138
21/06/2011	09:55	2,12	1120	191
06/07/2011	15:25	1,71	861	129
30/07/2011	11:35	2,56	1370	308
30/08/2011	11:10	1,9	1038	186
05/10/2011	12:25	2,04	1127	177
02/11/2011	10:45	2,97	1691	306
23/11/2011	11:20	3,01	1714	181
04/01/2012	12:10	2,24	1245	117
22/02/2012	11:20	1,39	742	75
29/03/2012	13:10	1,23	647	89
25/04/2012	13:10	1,31	696	89
30/05/2012	13:20	2,47	1407	408
27/06/2012	13:15	1,35	716	80
01/08/2012	11:40	2,53	1420	106
14/11/2012	01:12	2,91	1654	165
19/12/2012	10:35	1,68	909	61
30/01/2013	11:05	1,11	579	87
30/01/2013	11:00	1,11	579	134
06/03/2013	11:45	1,26	664	102
23/04/2013	11:10	0,7	350	91
29/05/2013	10:20	1,05	545	122
26/06/2013	09:45	2,83	1605	229

APPENDIX E

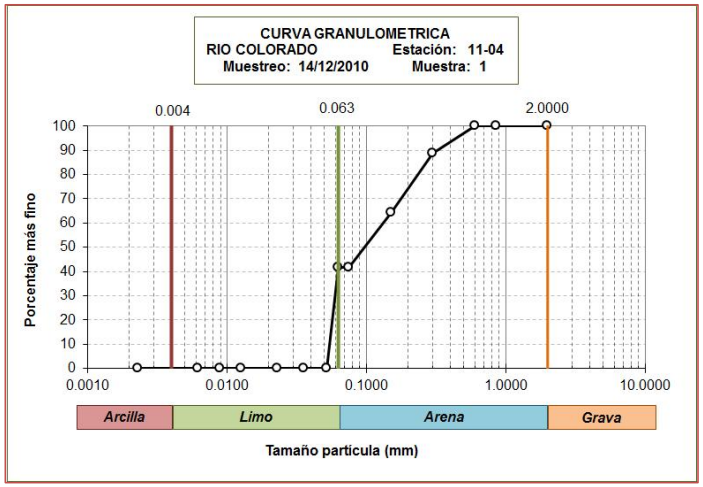
GRAIN SIZE DISTRIBUTION FOR BED-LOAD SAMPLES, TAKEN IN A MONTHLY BASIS WITHIN THE PERIOD DECEMBER 2010 - JUNE 2013 AT THE MOUTHS OF THE SAN CARLOS AND SARAPIQUÍ RIVERS, AND AT DELTA COLORADO STATION (11-04)

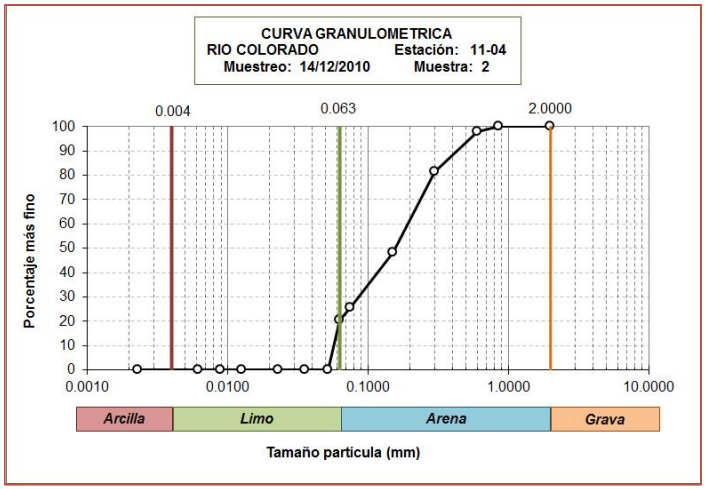
Bed-load sediment: Particle size distribution

Station 11-04 Delta Colorado

Station 11-04 Delta Colorado

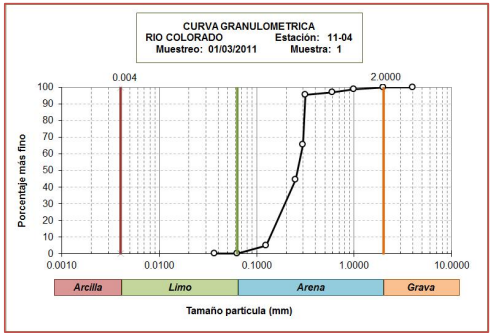
14 December 2010

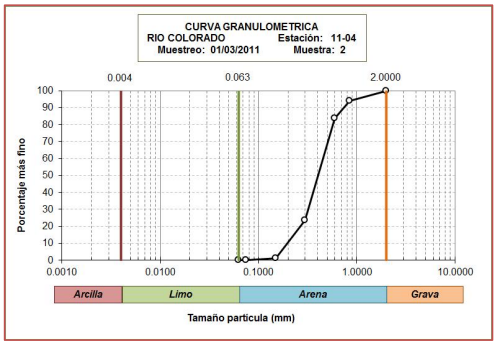


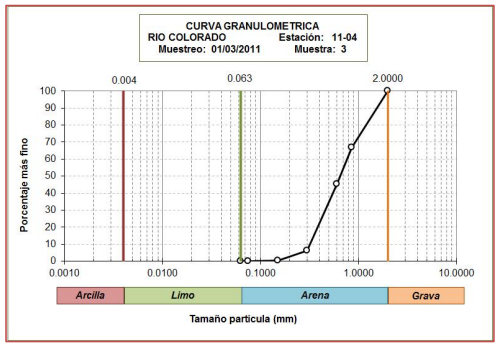


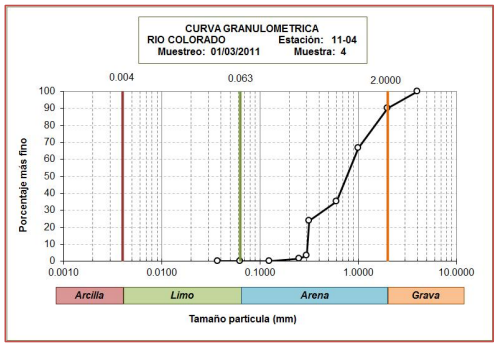
Station 11-04 Delta Colorado

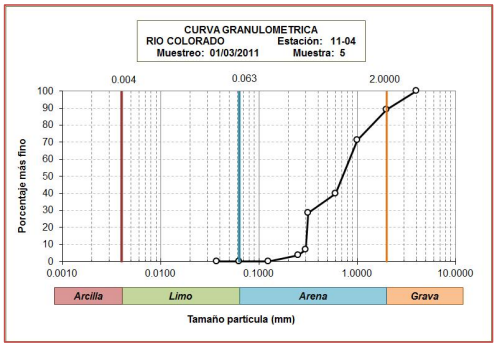
01 Mar 2011





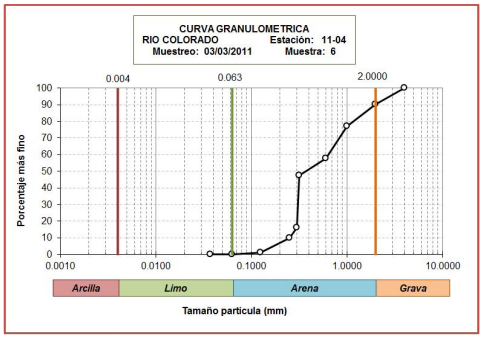


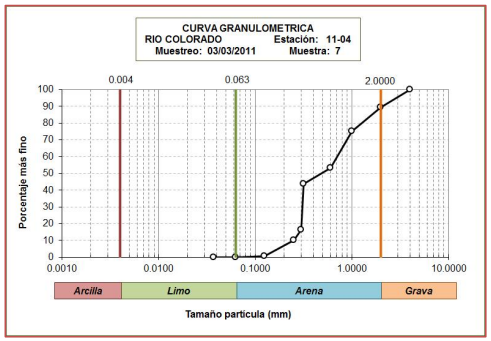


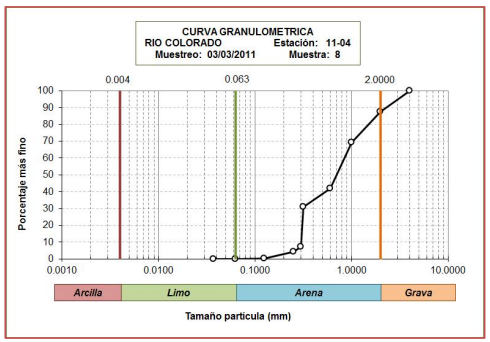


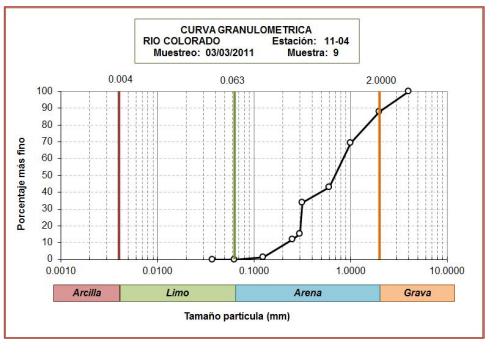
Station 11-04 Delta Colorado

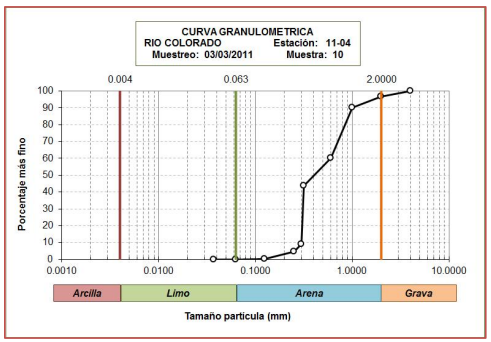
03 Mar 2011





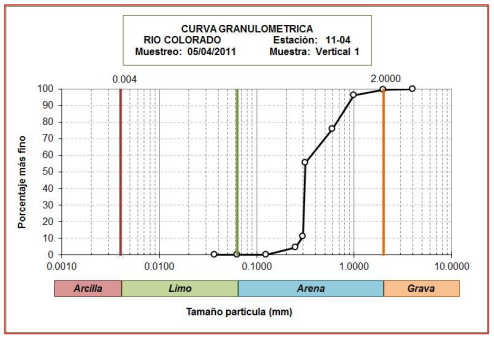


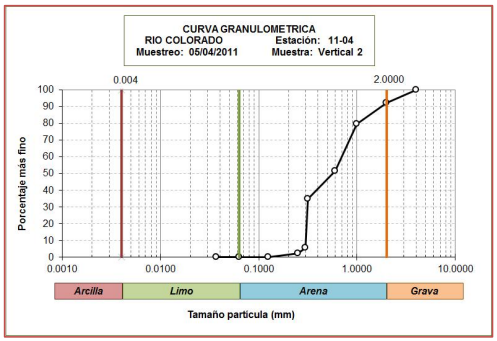


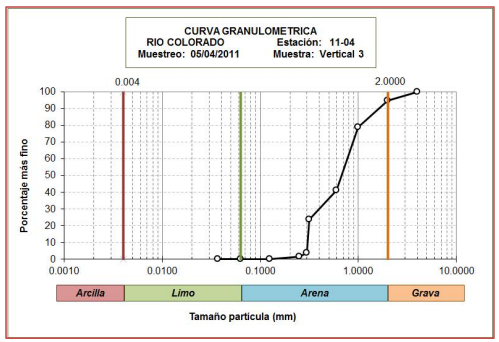


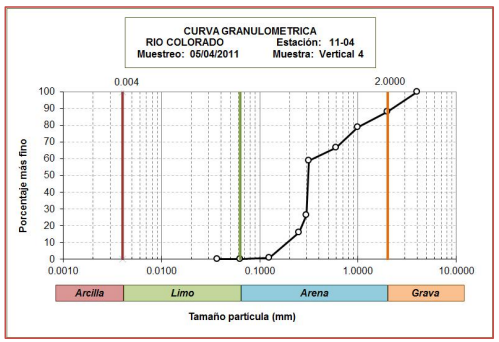
Station 11-04 Delta Colorado

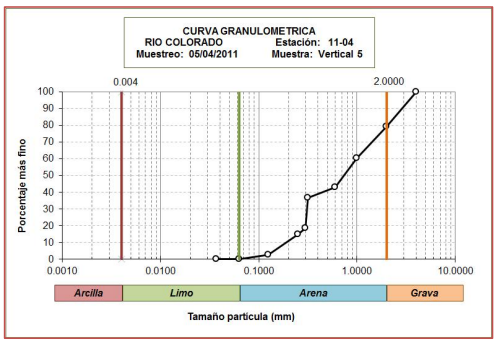
05 Apr 2011





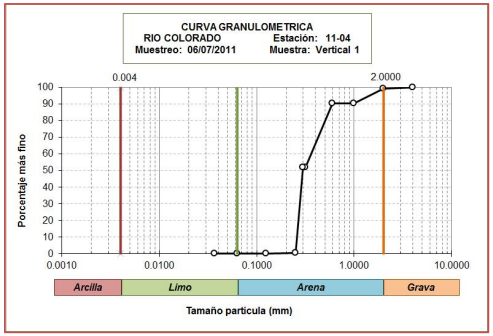


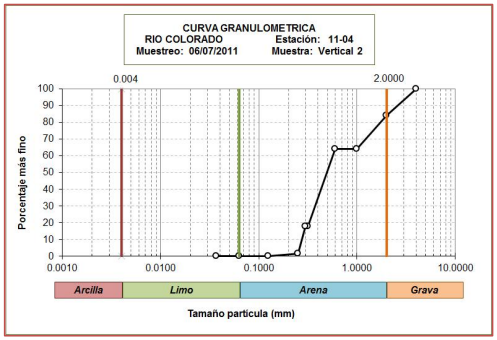


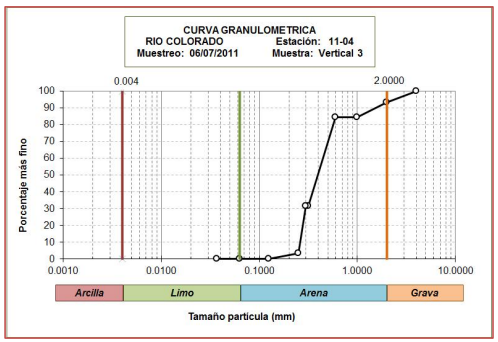


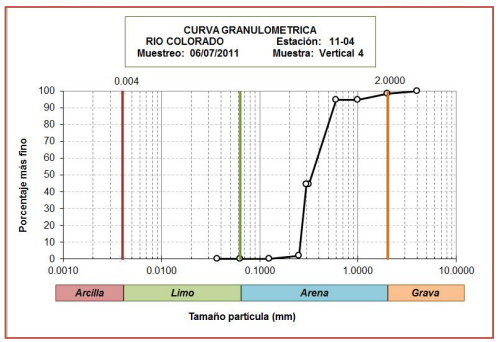
Station 11-04 Delta Colorado

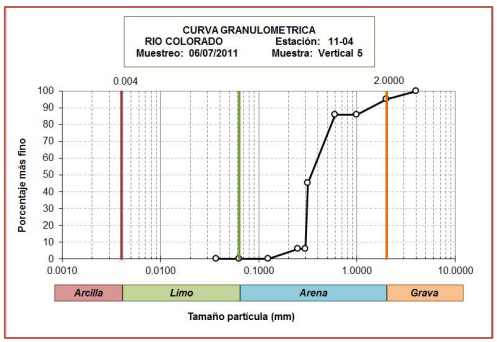
06 Jul 2011





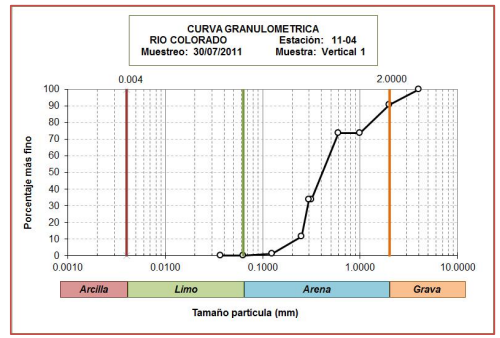


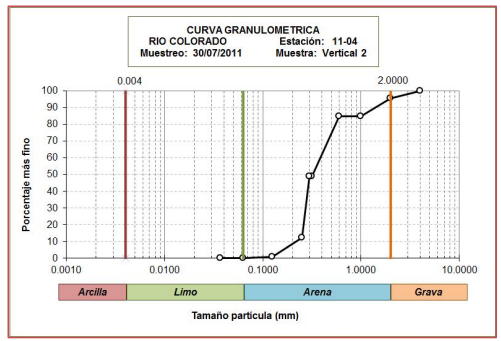


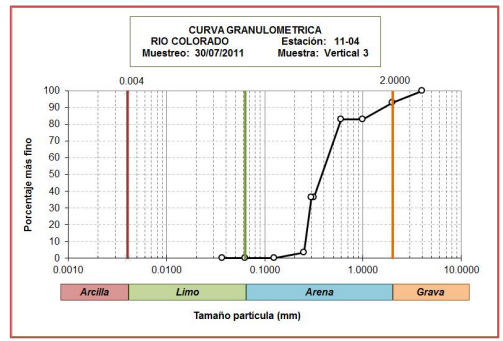


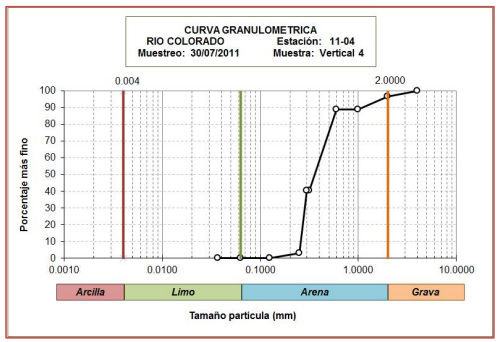
Station 11-04 Delta Colorado

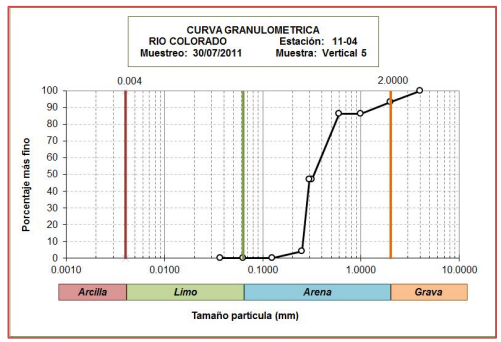
30 Jul 2011

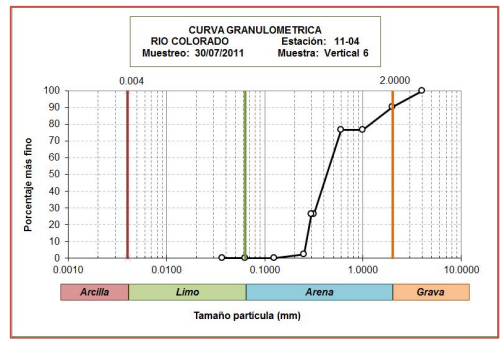






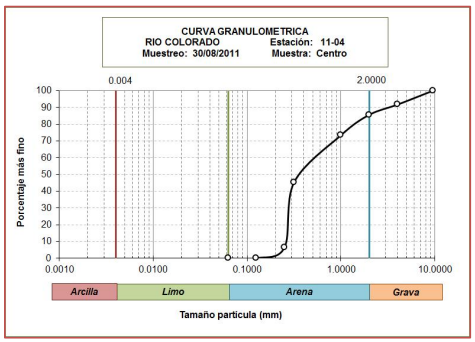


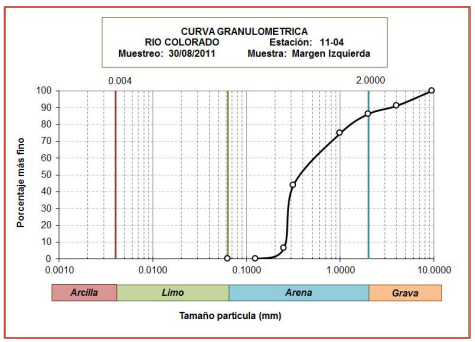


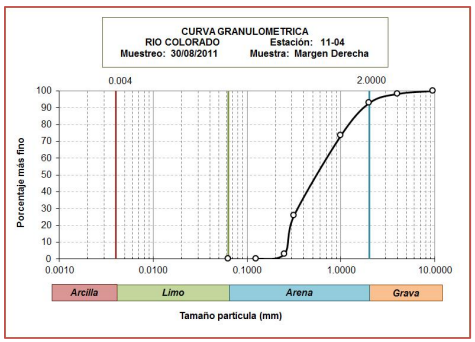


Station 11-04 Delta Colorado

30 Aug 2011

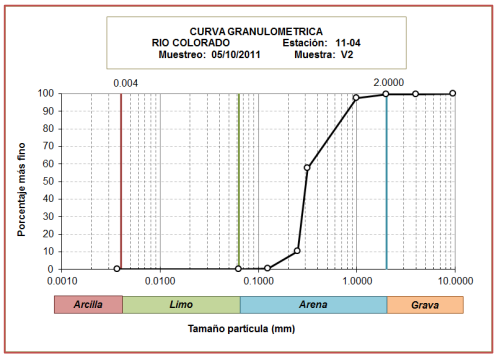


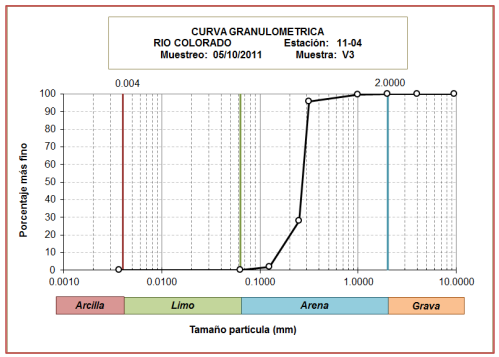


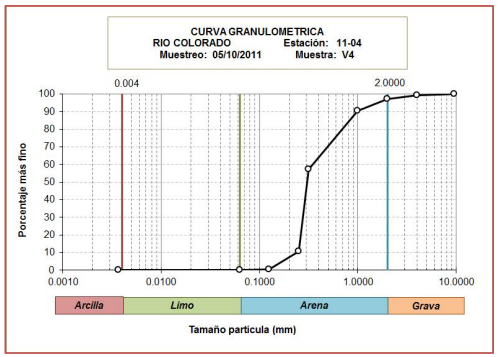


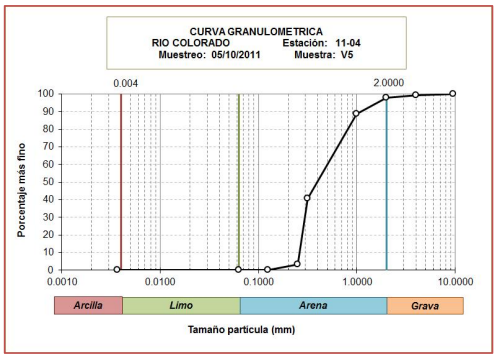
Station 11-04 Delta Colorado

05 Oct 2011



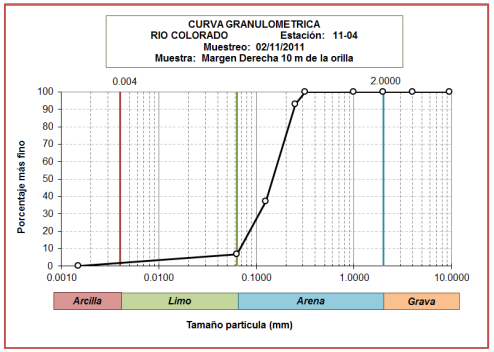


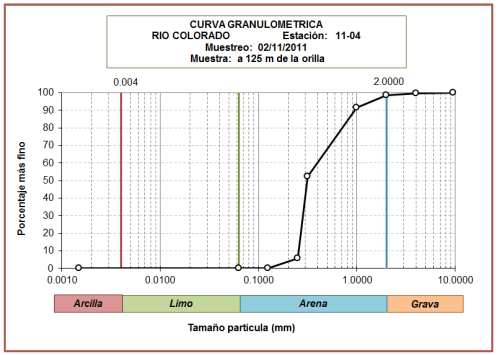


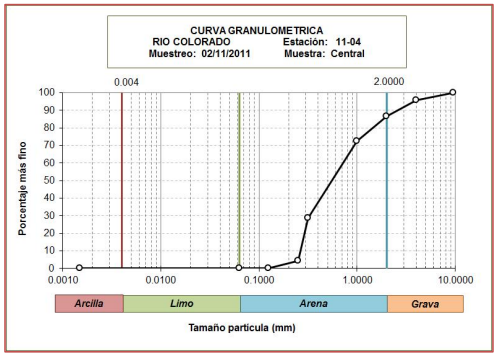


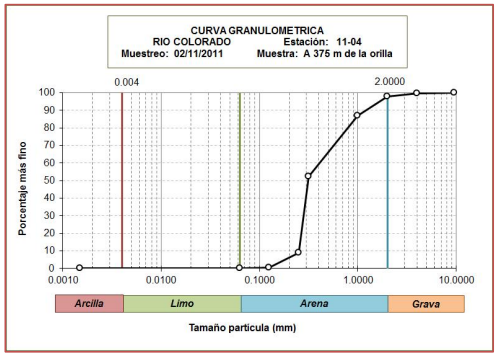
Station 11-04 Delta Colorado

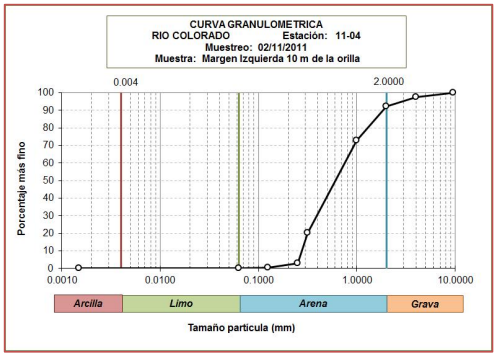
02 Nov 2011





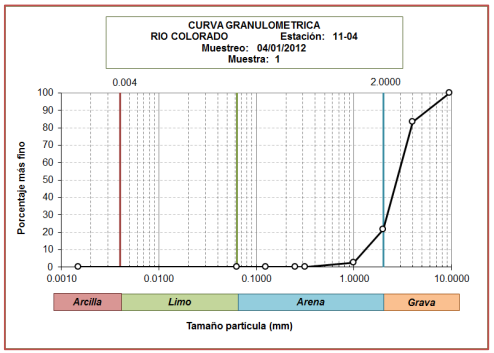


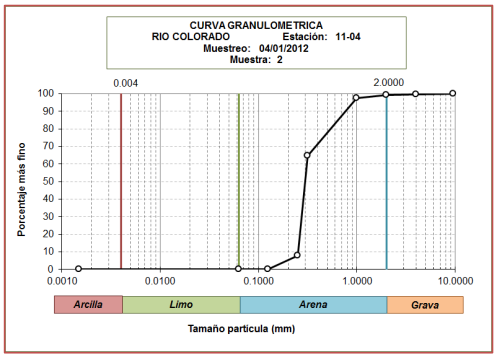


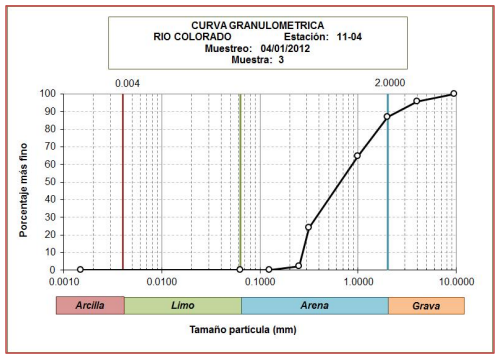


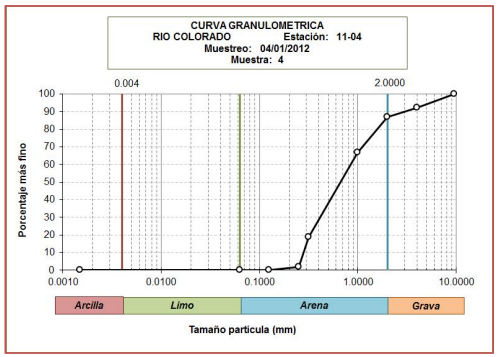
Station 11-04 Delta Colorado

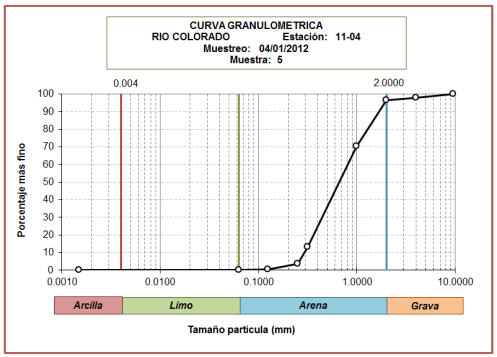
01 Jan 2012





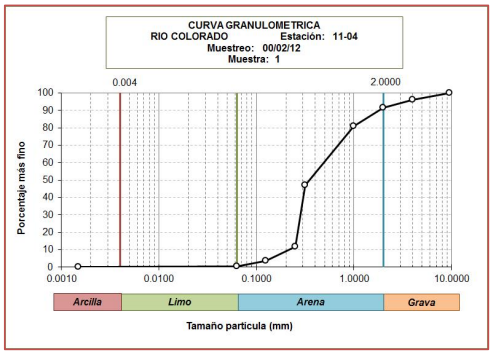


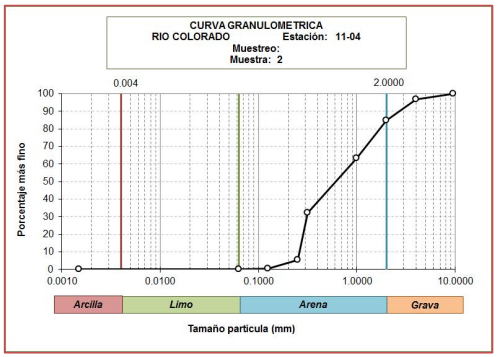


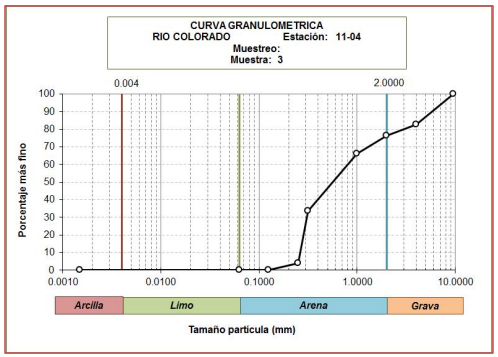


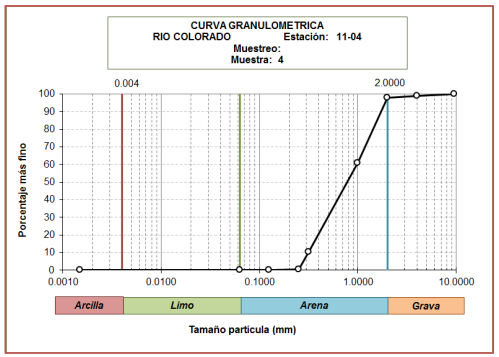
Station 11-04 Delta Colorado

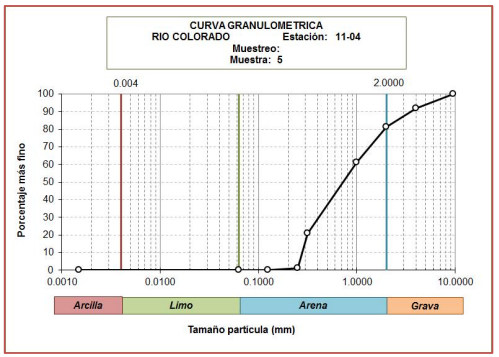
22 Feb 2012





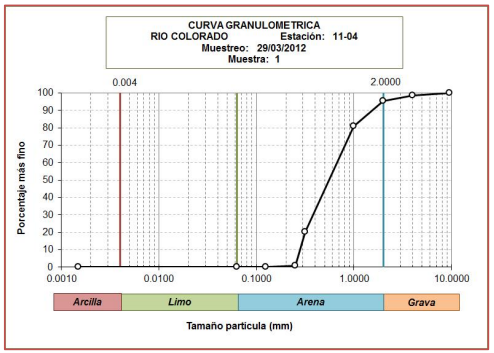


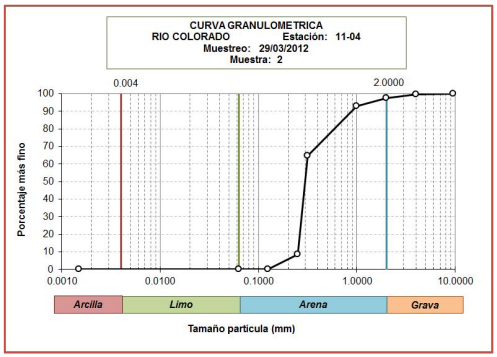


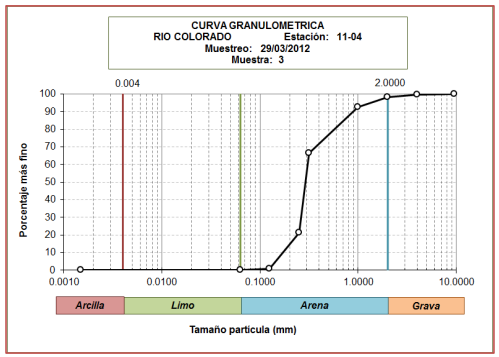


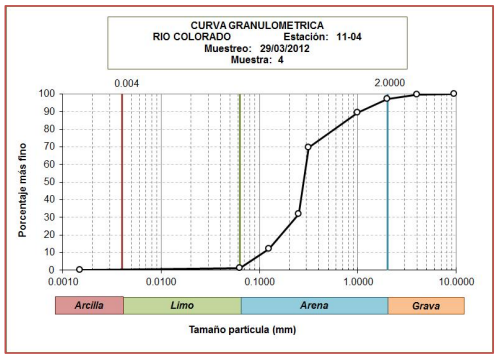
Station 11-04 Delta Colorado

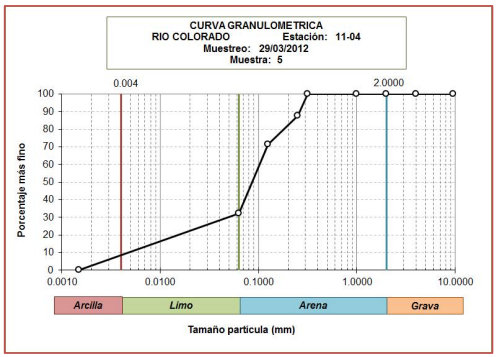
29 Mar 2012





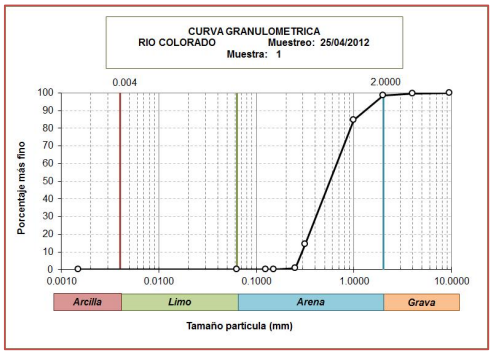


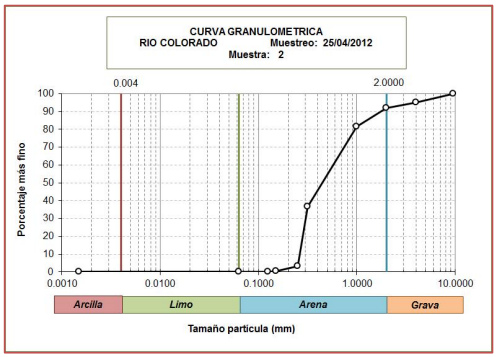


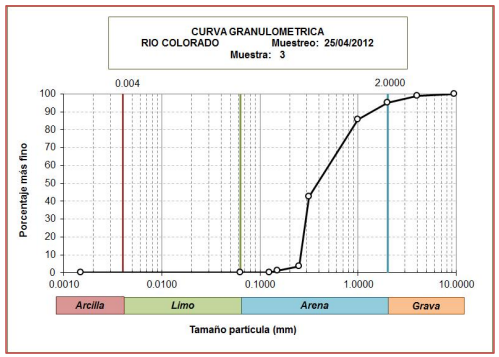


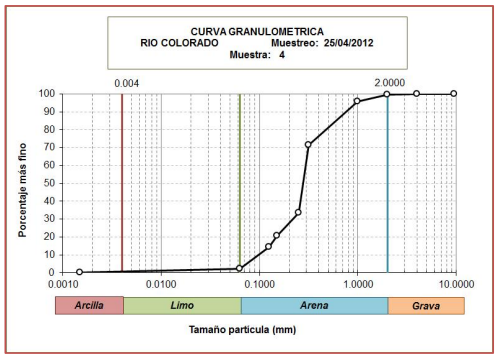
Station 11-04 Delta Colorado

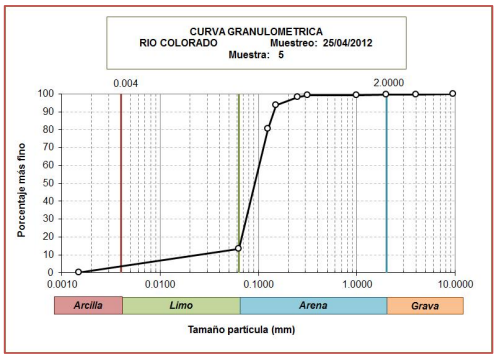
25 Apr 2012





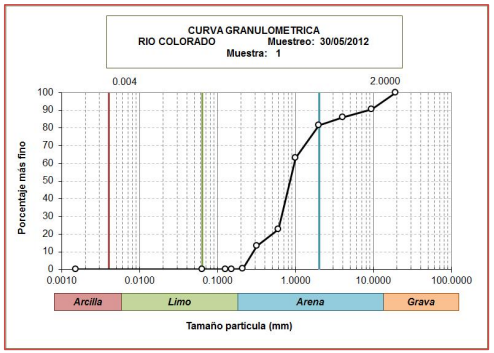


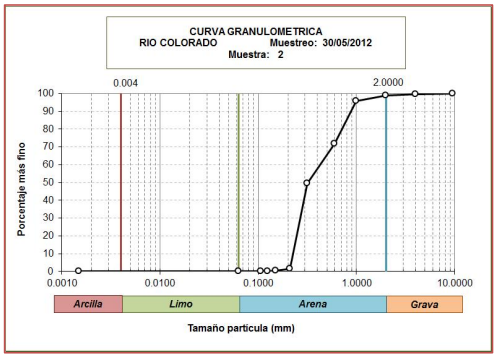


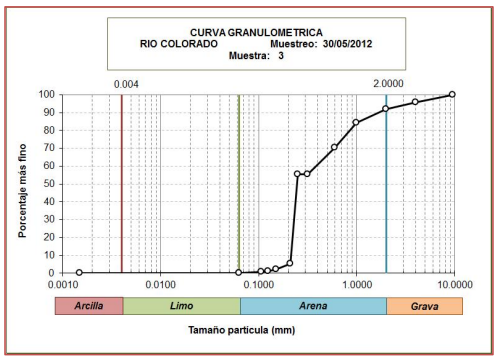


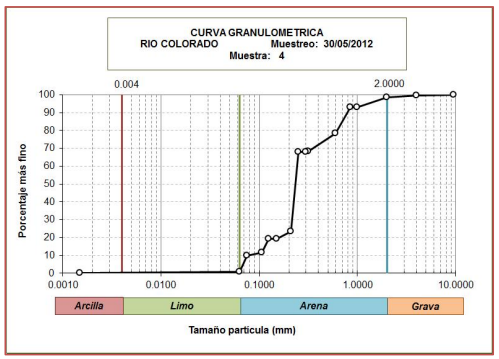
Station 11-04 Delta Colorado

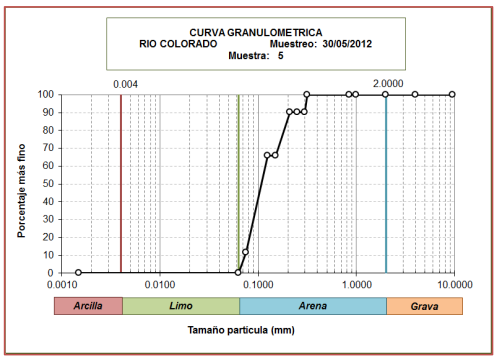
30 May 2012





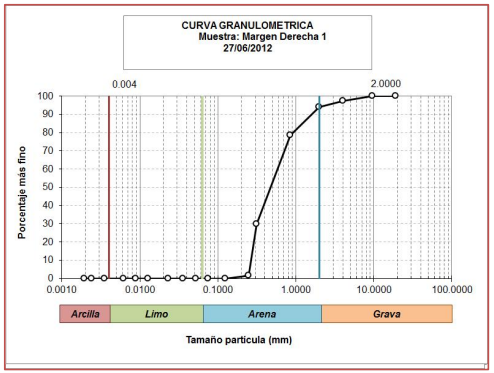


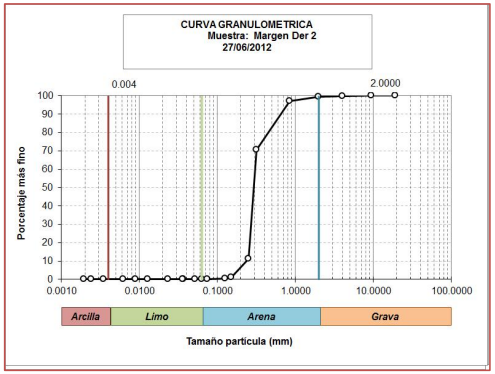


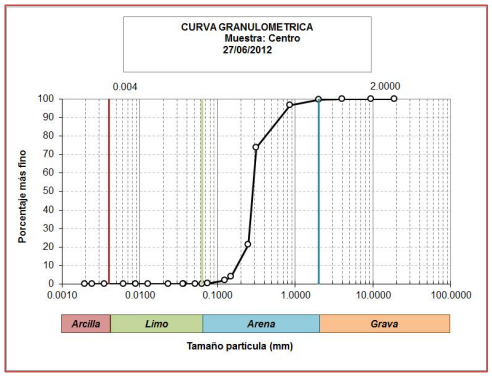


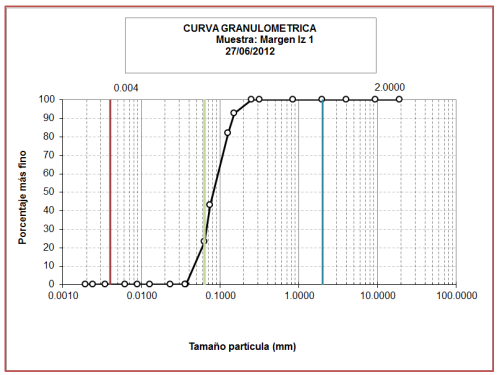
Station 11-04 Delta Colorado

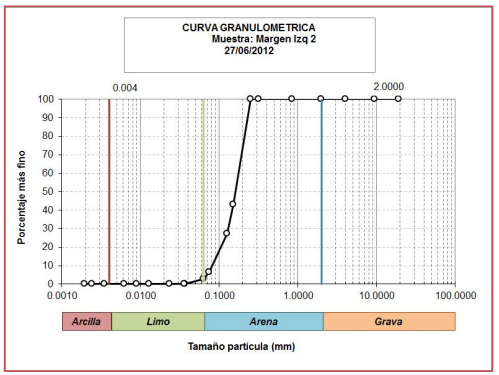
27 Jun 2012





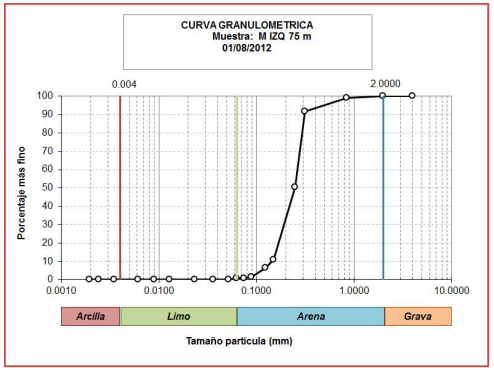


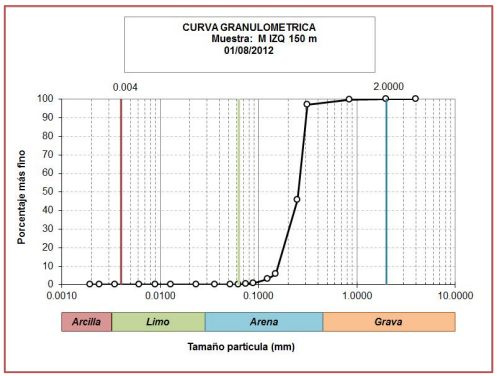


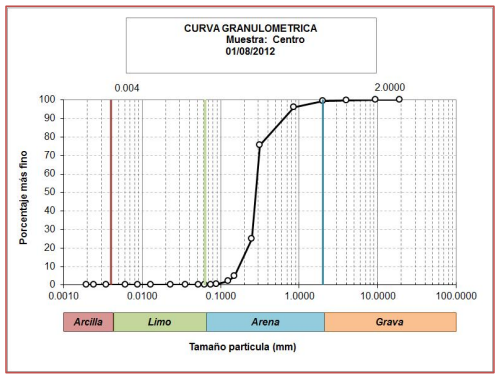


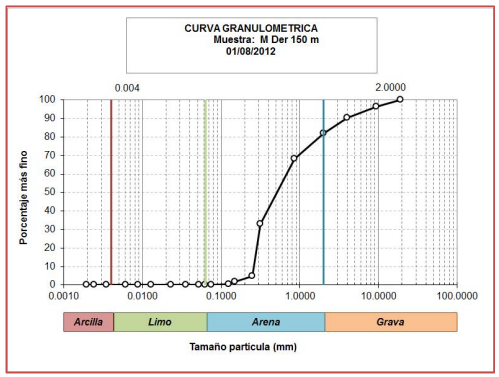
Station 11-04 Delta Colorado

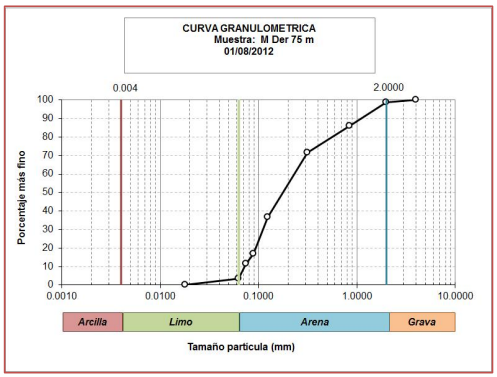
01 Aug 2012





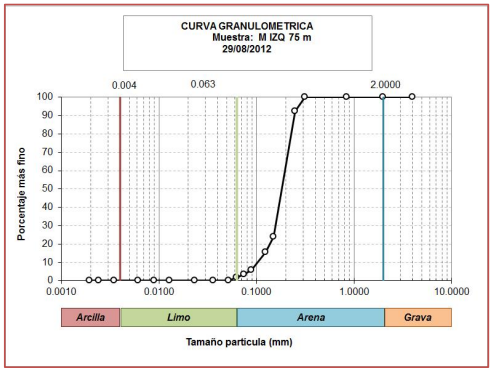


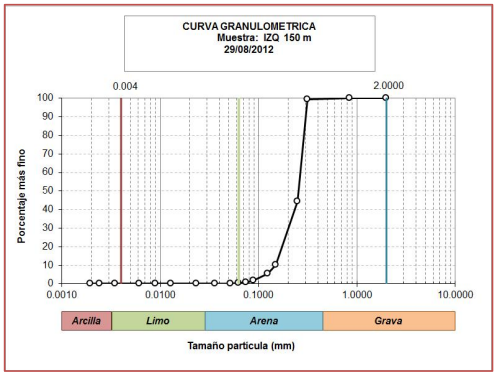


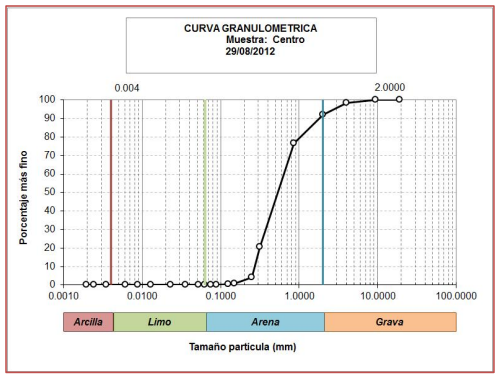


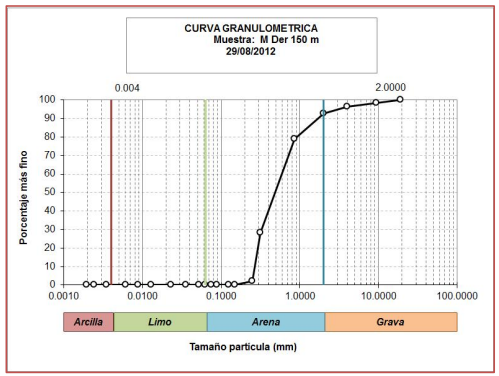
Station 11-04 Delta Colorado

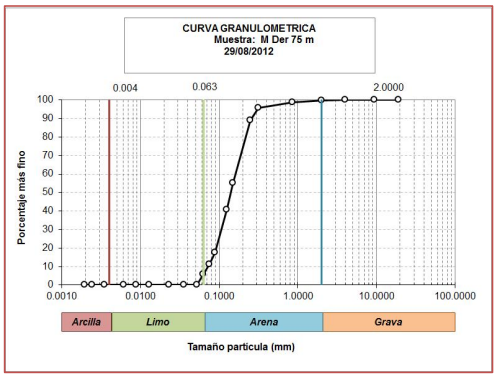
29 Aug 2012





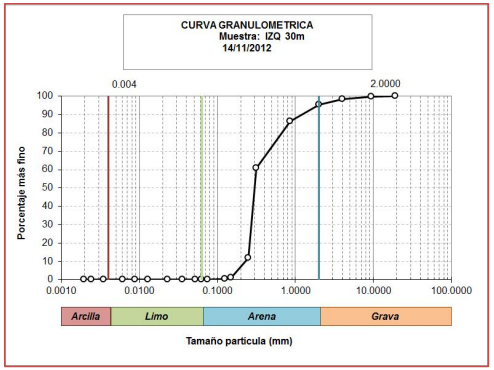


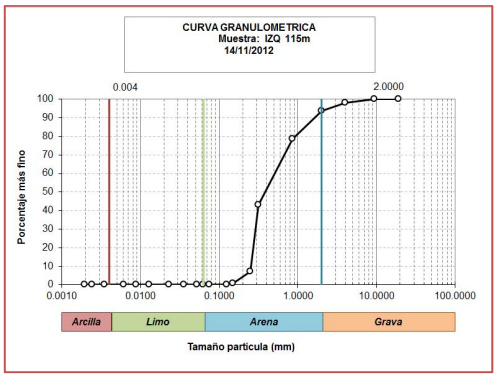


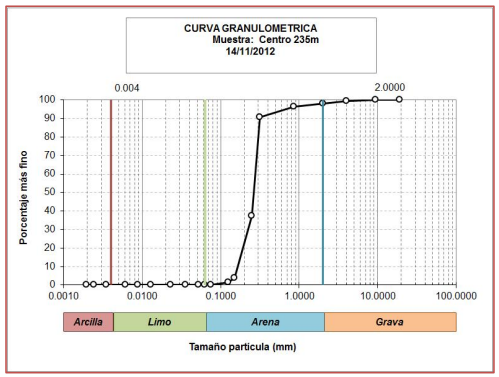


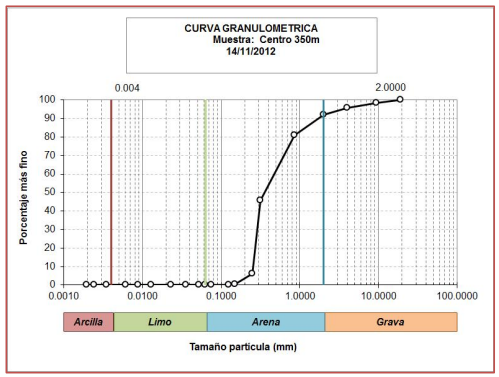
Station 11-04 Delta Colorado

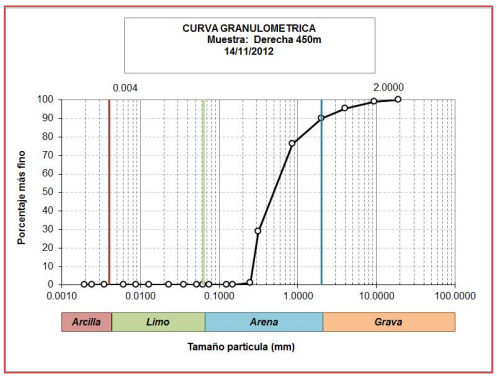
14 Nov 2012





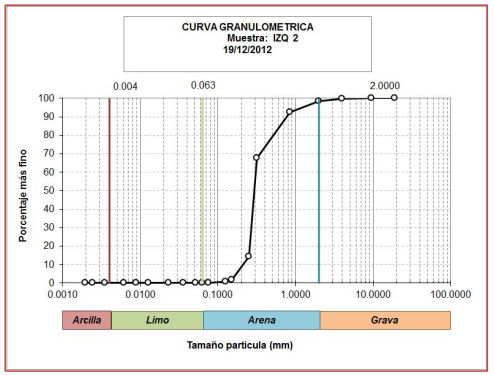


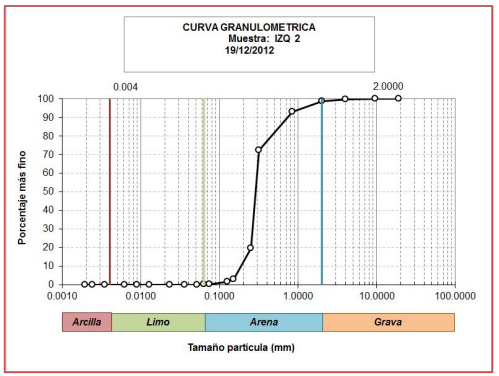


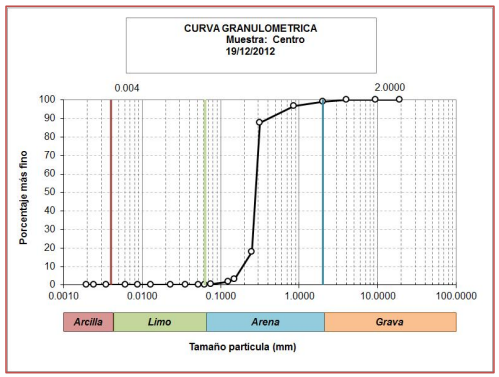


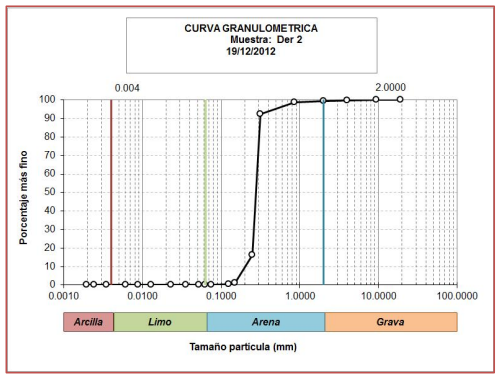
Station 11-04 Delta Colorado

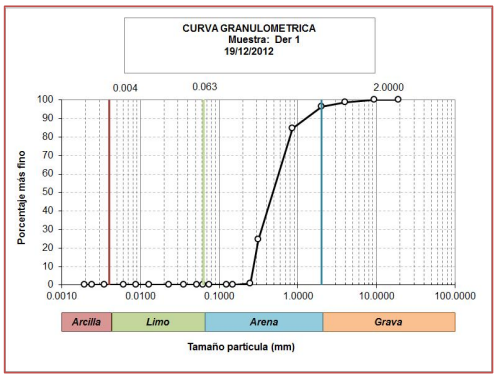
19 Dec 2012





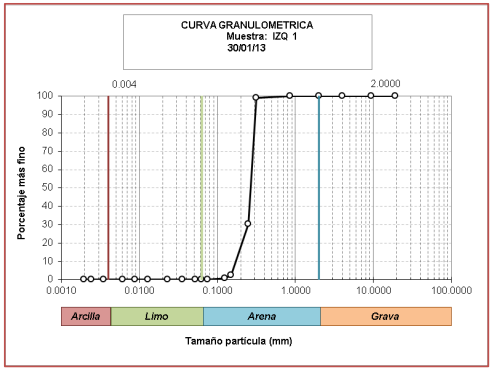


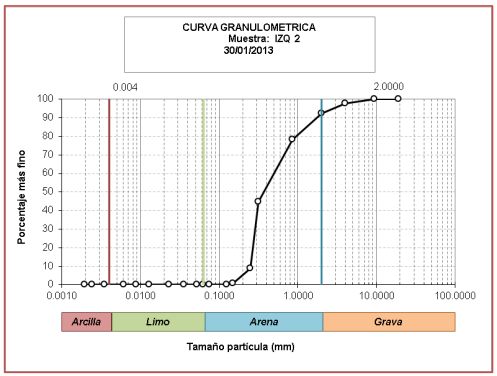


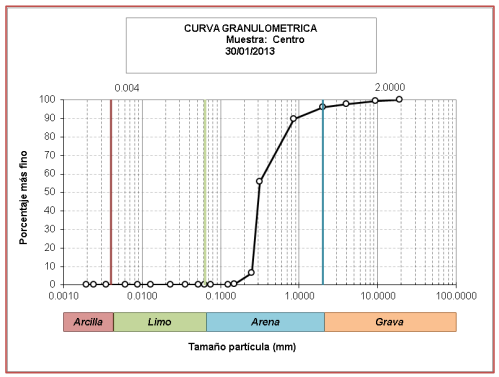


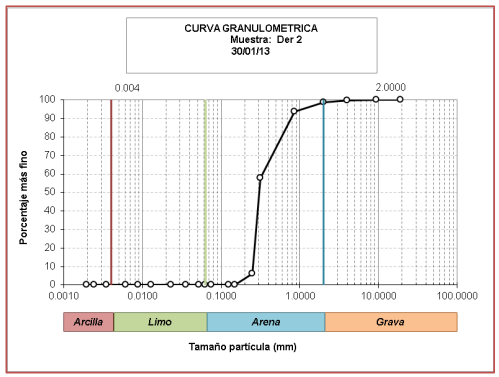
Station 11-04 Delta Colorado

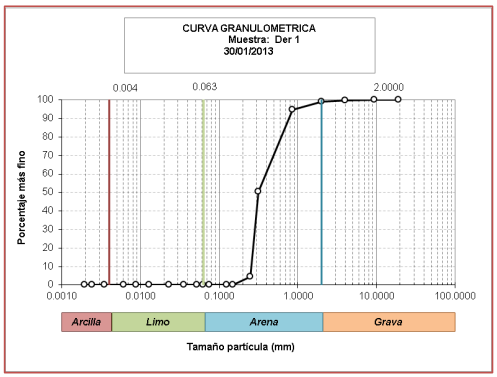
30 Jan 2013





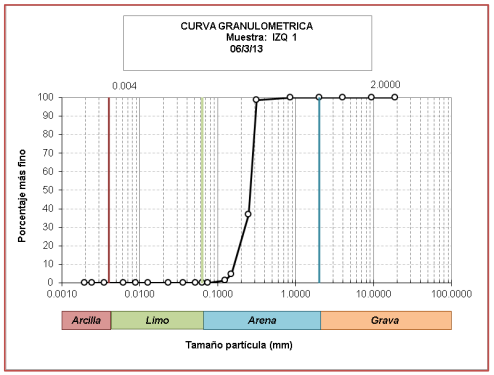


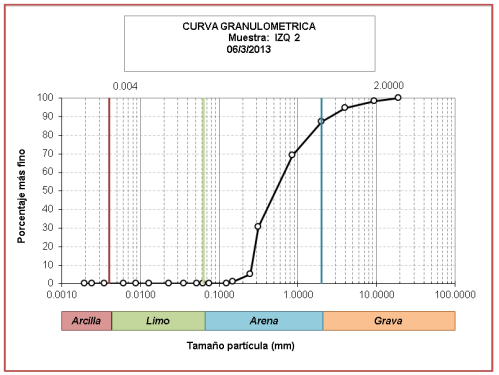


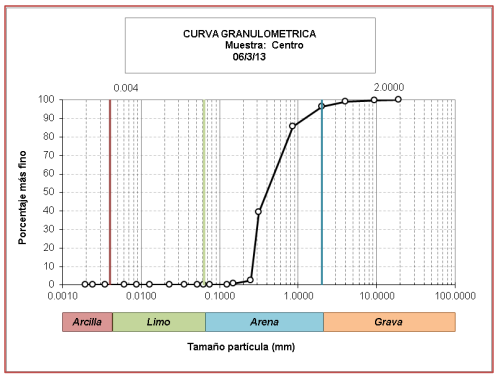


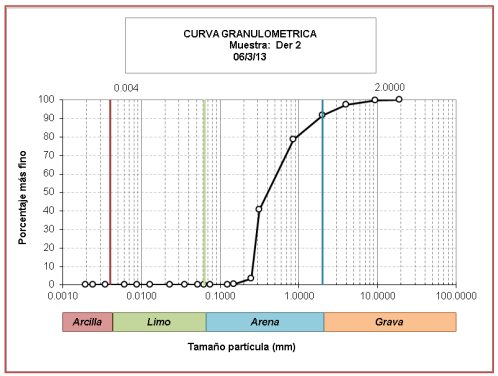
Station 11-04 Delta Colorado

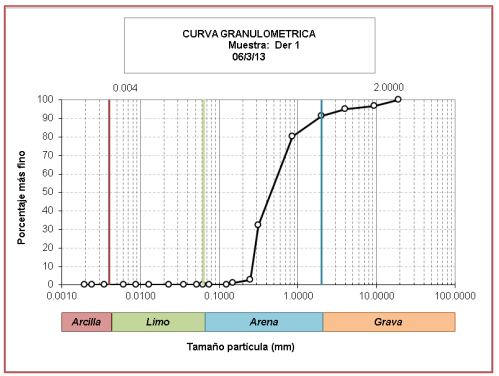
06 Mar 2013





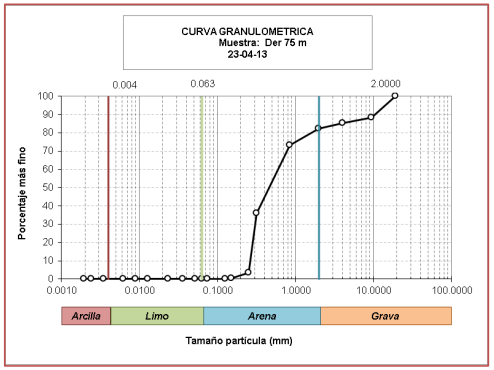


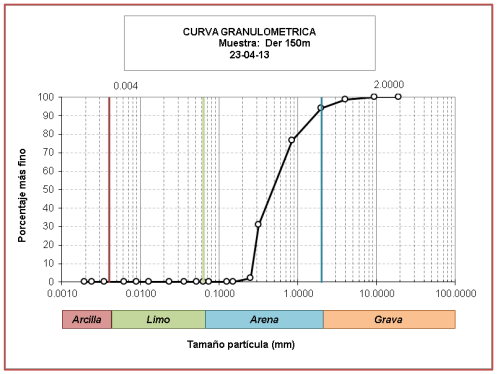


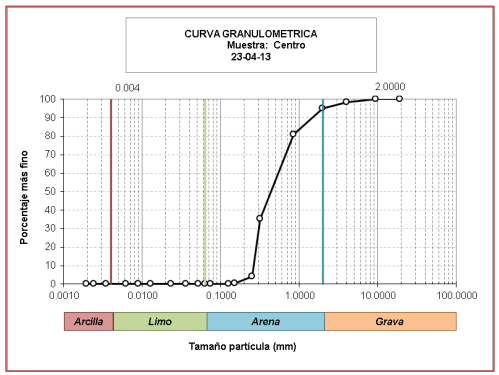


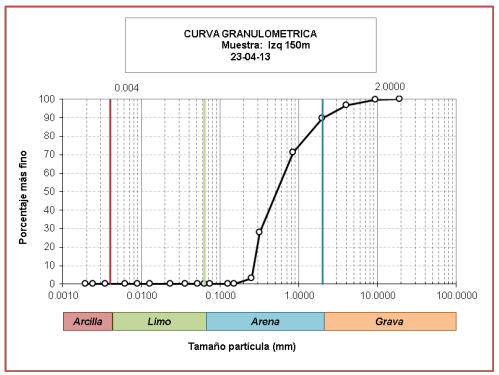
Station 11-04 Delta Colorado

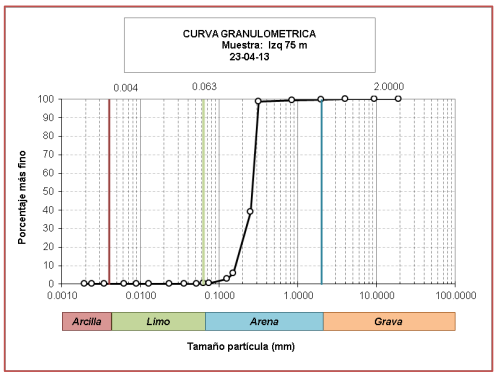
22 Apr 2013





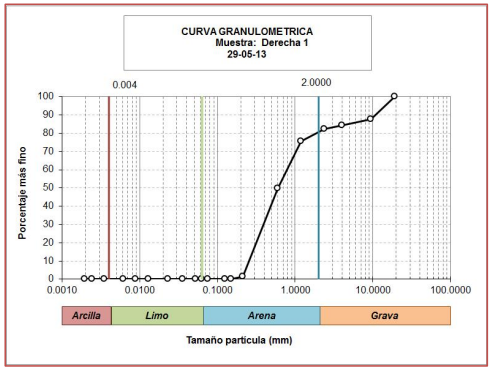


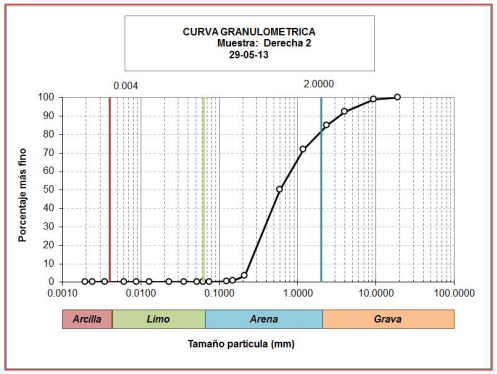


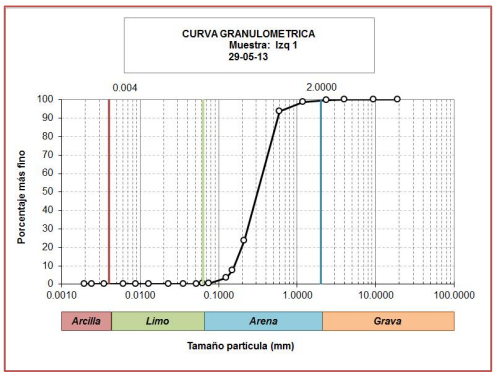


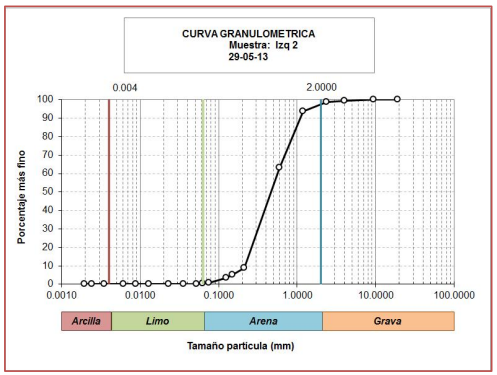
Station 11-04 Delta Colorado

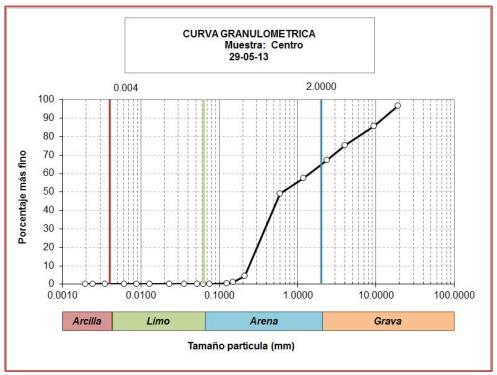
29 May 2013





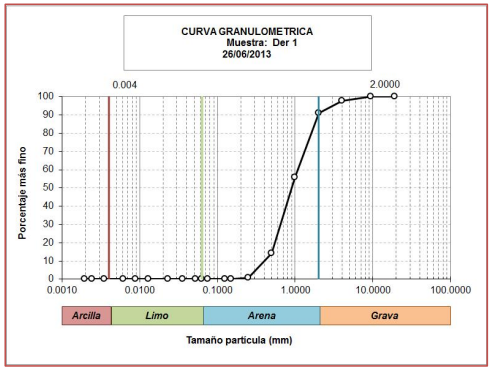


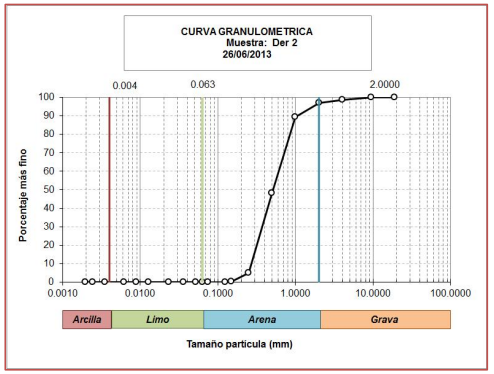


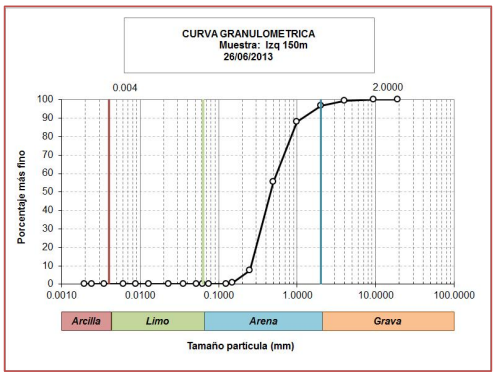


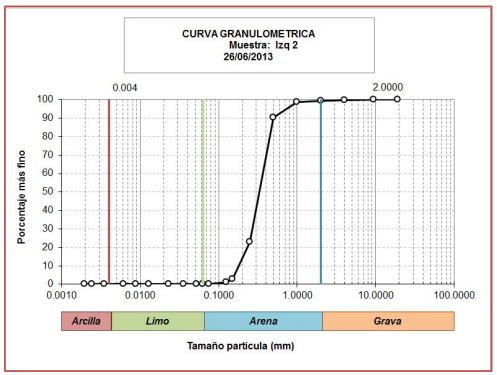
Station 11-04 Delta Colorado

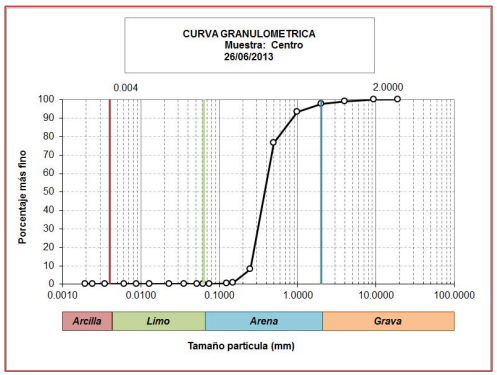
26 Jun 2013







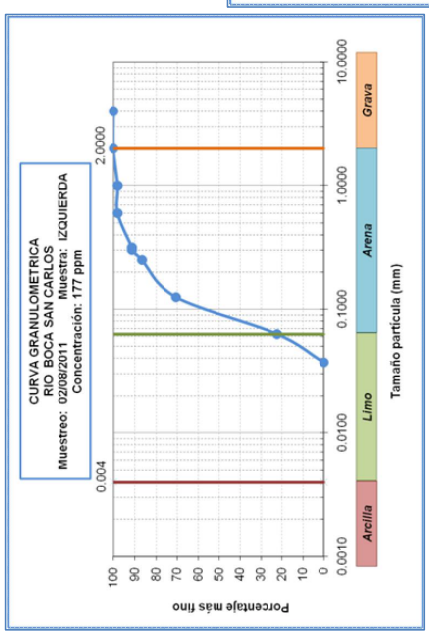


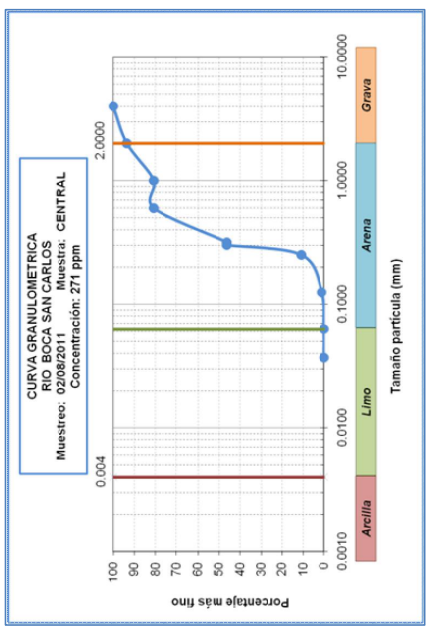


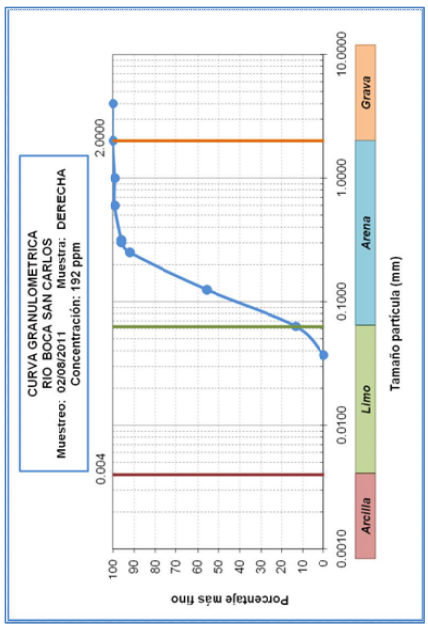
Bed-load sediment: Particle size distribution

Mouth of San Carlos River

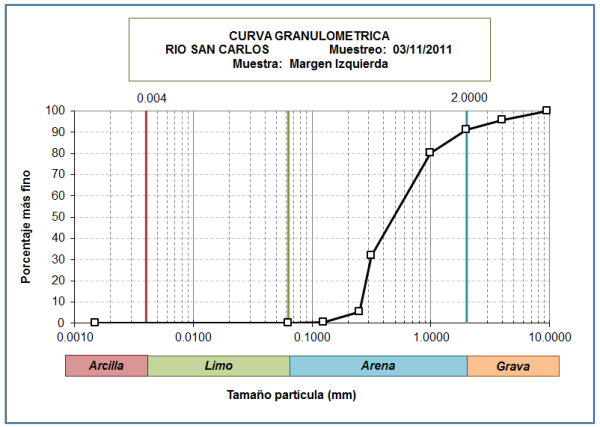
Mouth of San Carlos River
02 August 2011

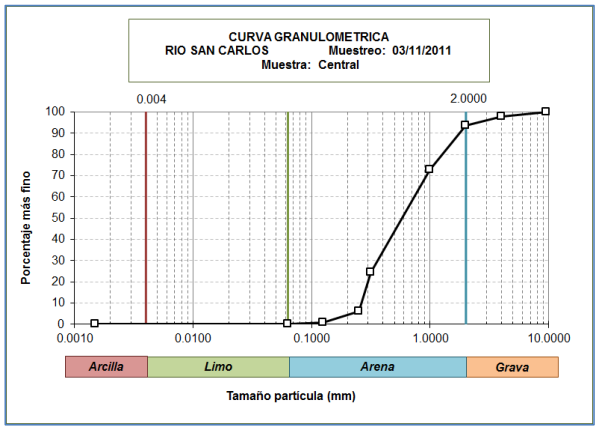


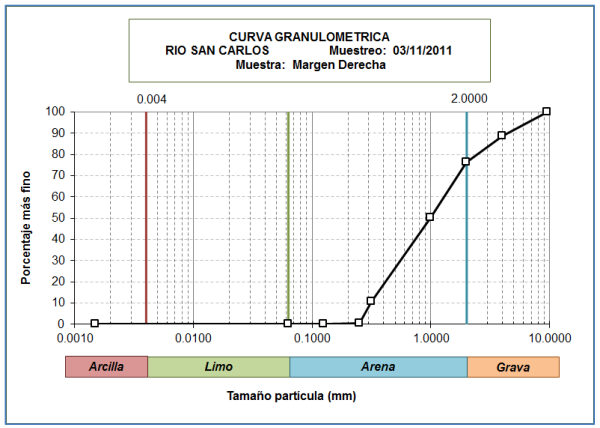




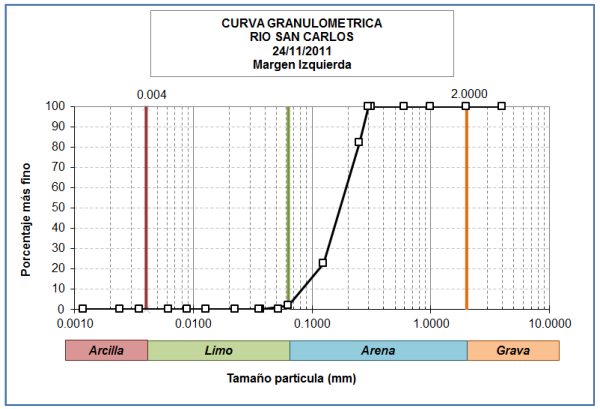
Mouth of San Carlos River
03 November 2011

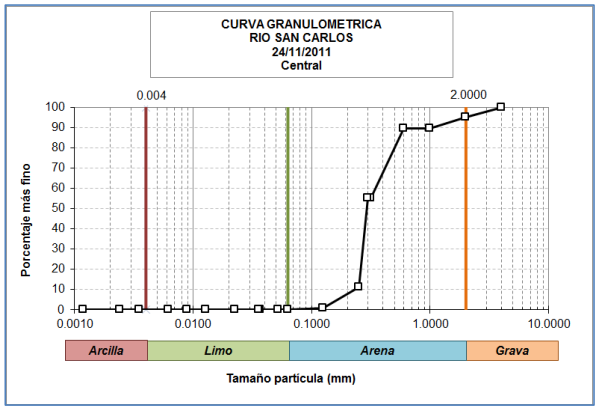


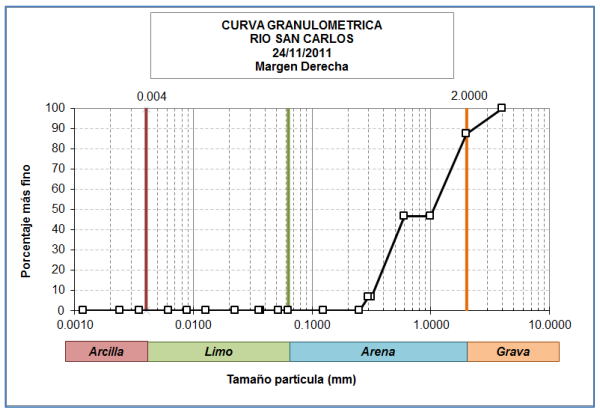




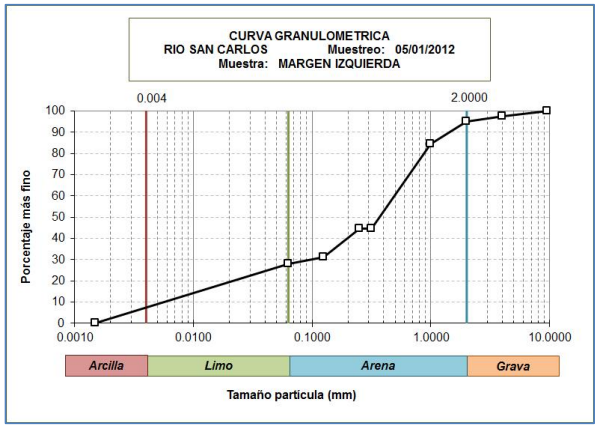
Mouth of San Carlos River
24 November 2011

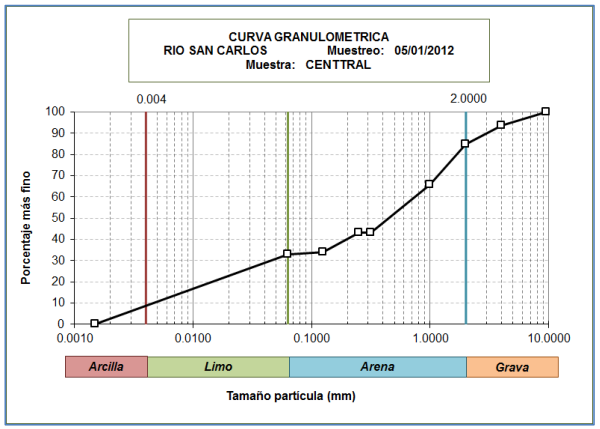


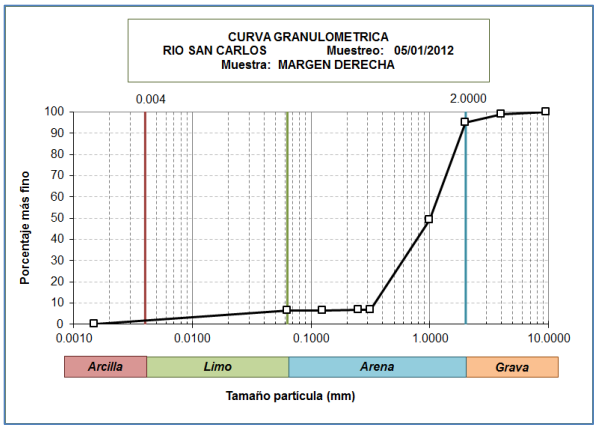




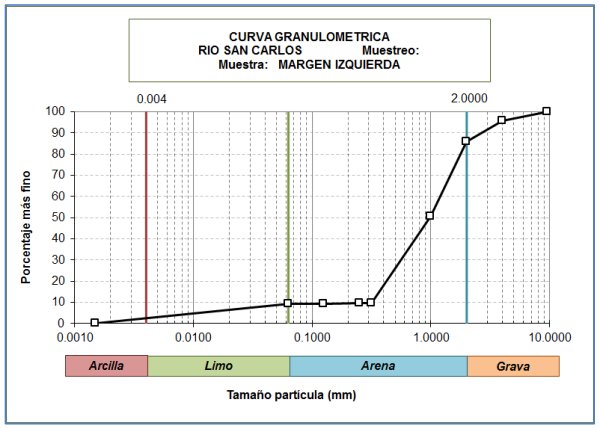
Mouth of San Carlos River
05 January 2012

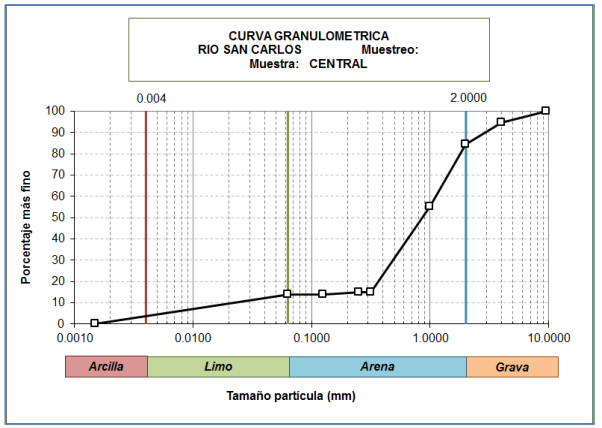


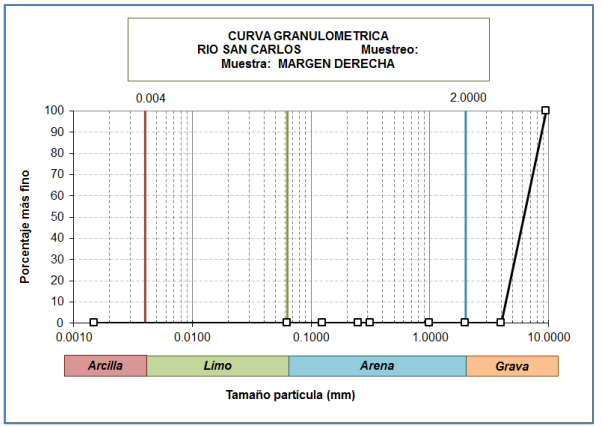




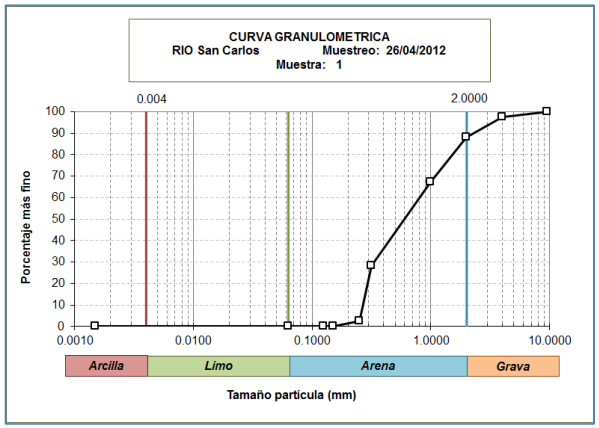
Mouth of San Carlos River
23 February 2012

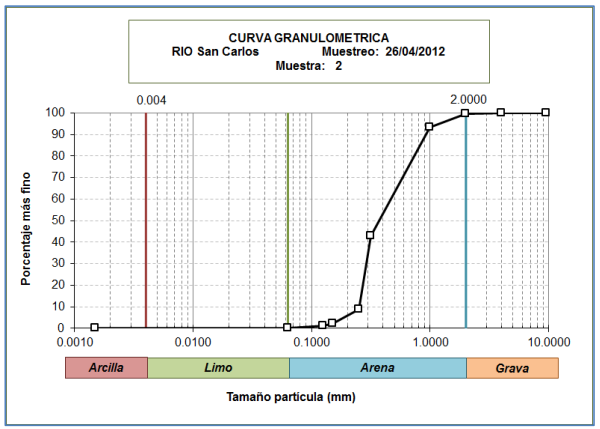


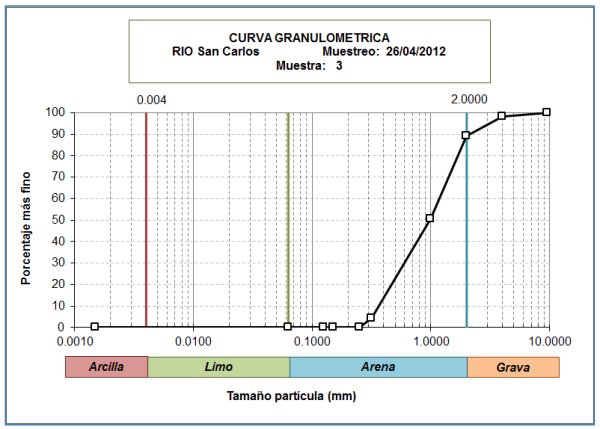




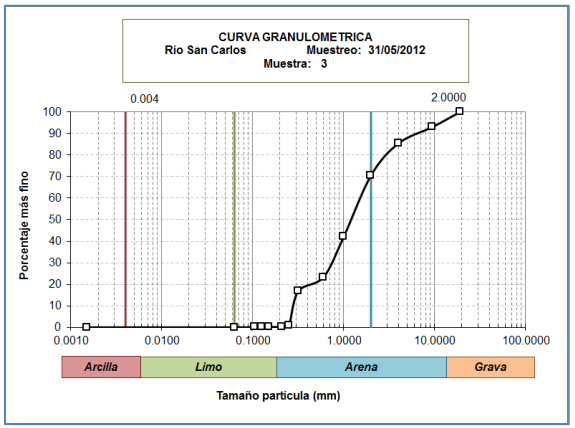
Mouth of San Carlos River
26 April 2012

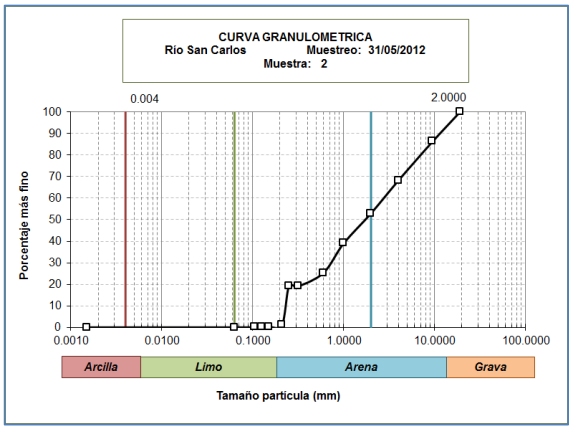


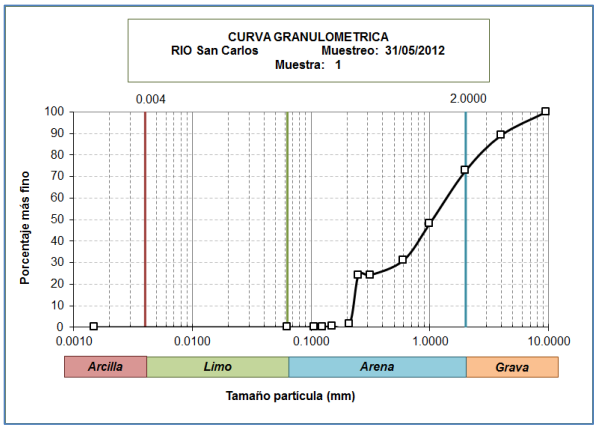




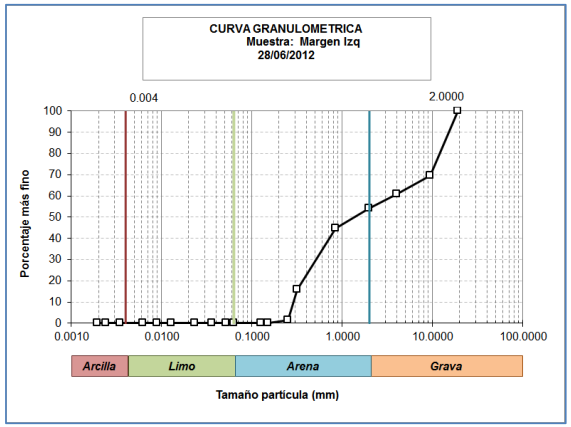
Mouth of San Carlos River
31 May 2012

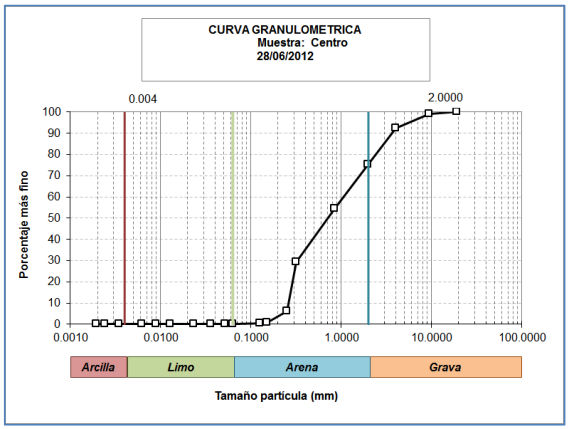


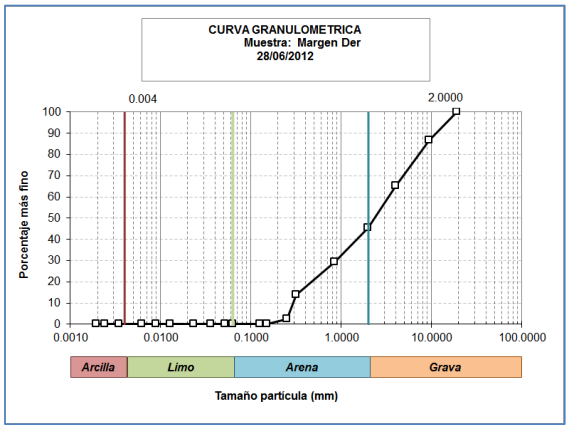




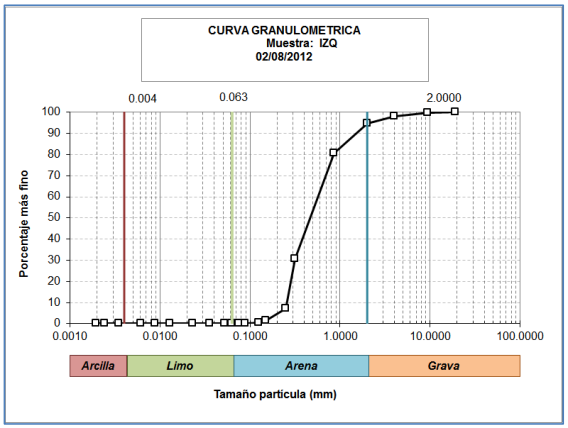
Mouth of San Carlos River
28 June 2012

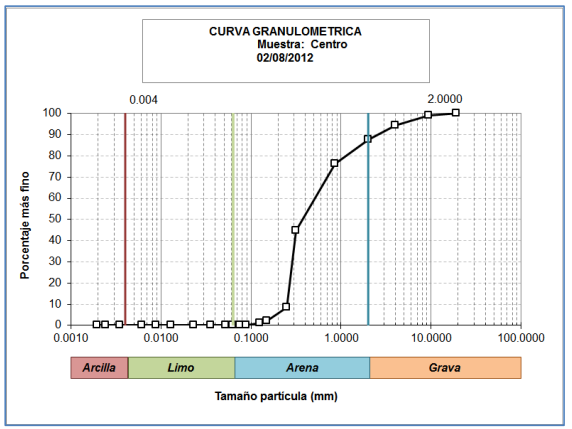


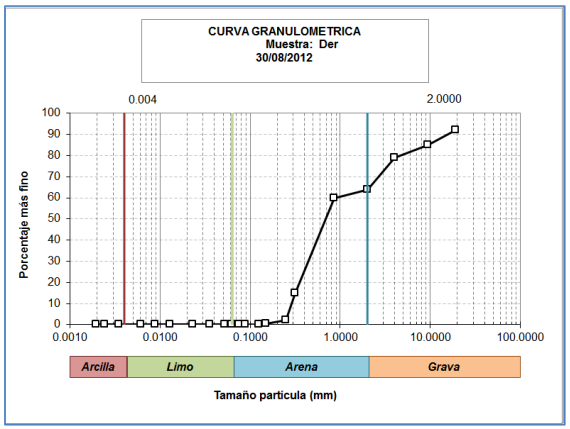




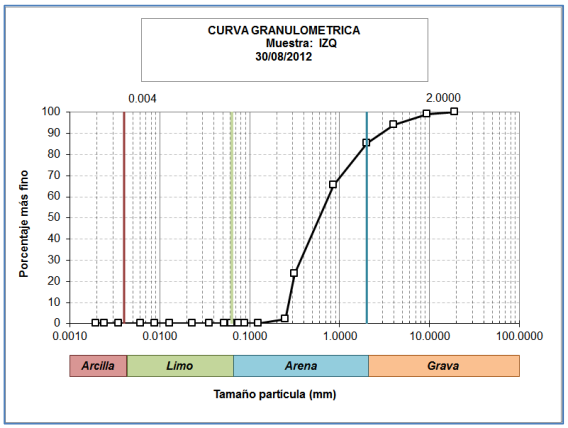
Mouth of San Carlos River
02 August 2012

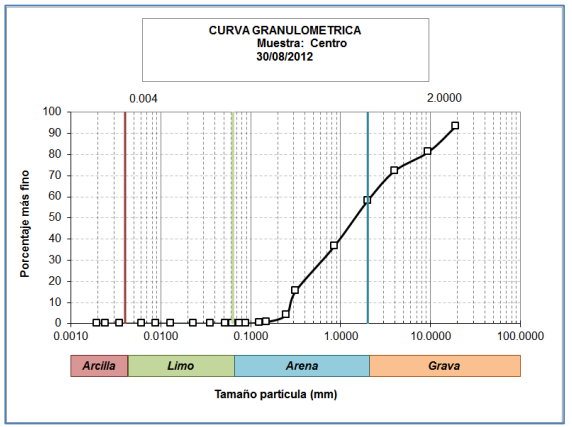


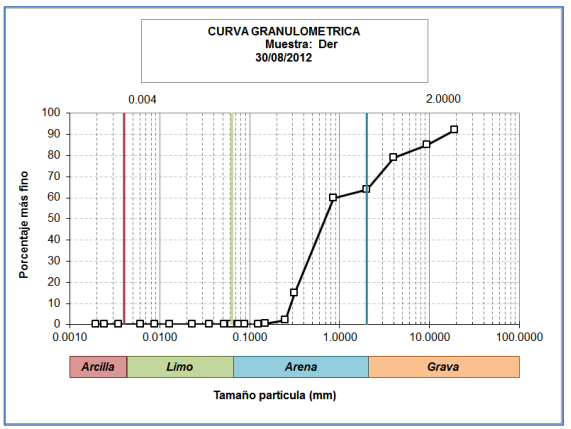




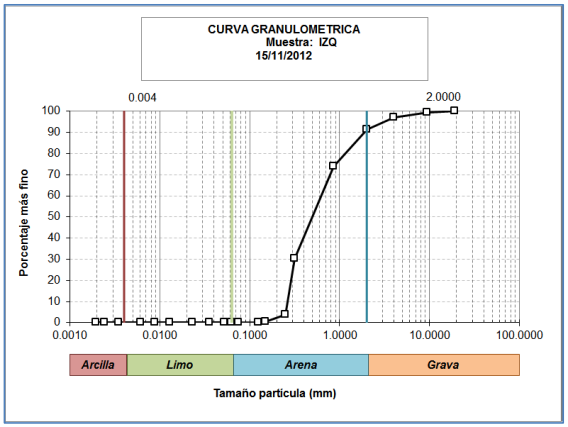
Mouth of San Carlos River
30 August 2012

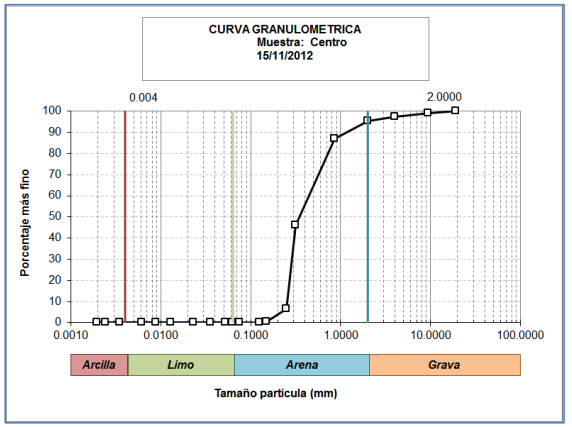


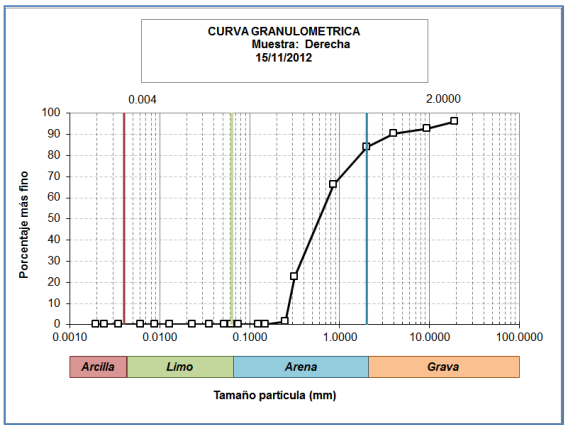




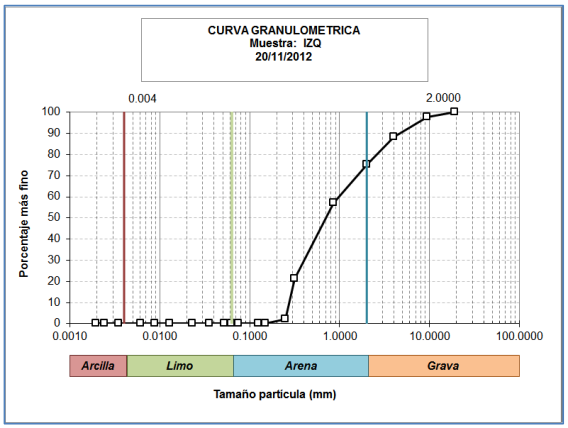
Mouth of San Carlos River
15 November 2012

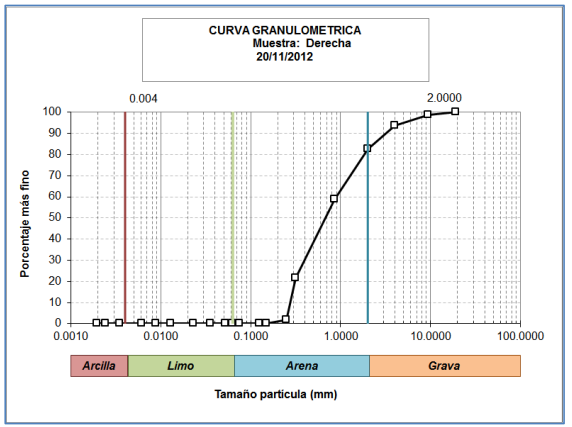


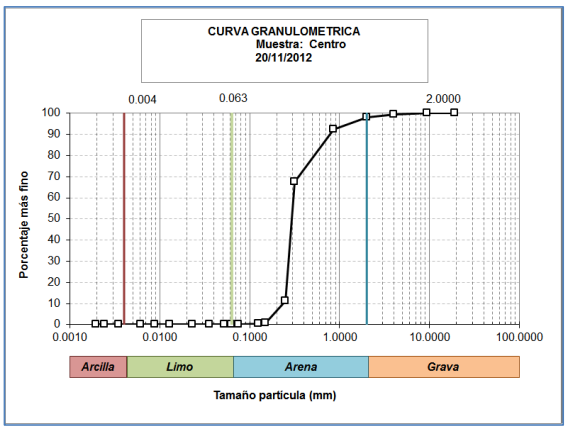




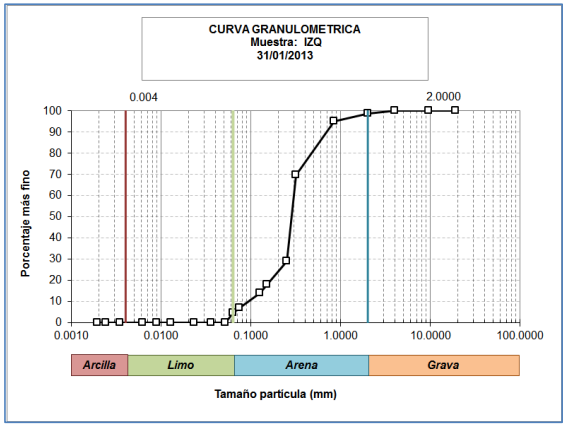
Mouth of San Carlos River
20 December 2012

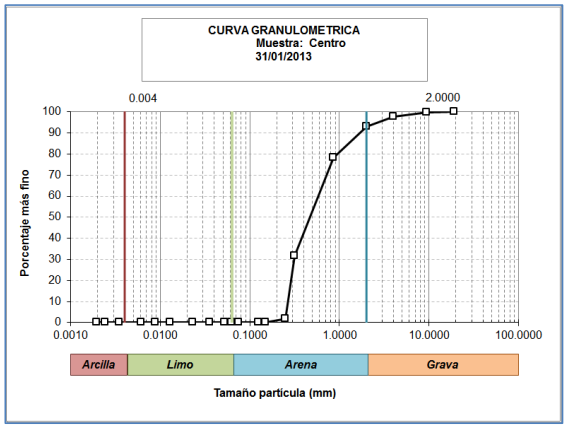


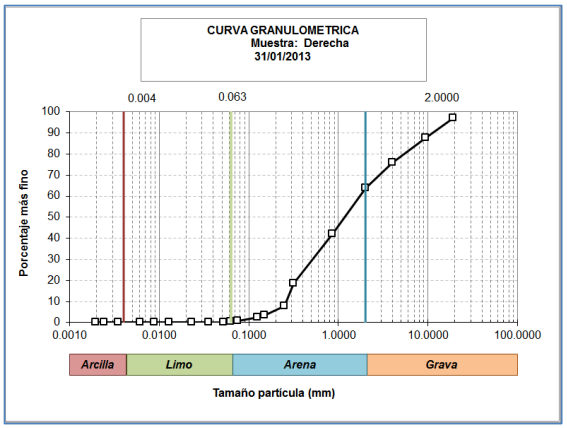




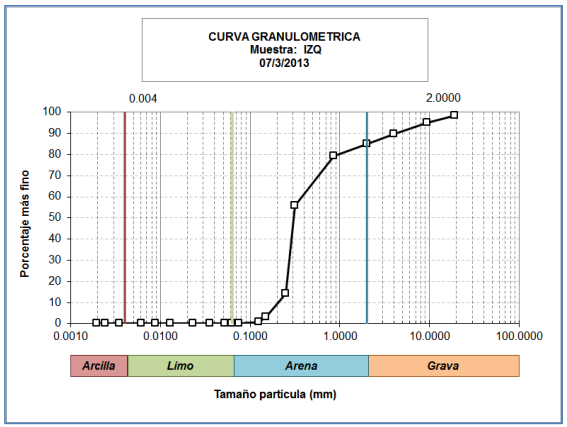
Mouth of San Carlos River
31 January 2013

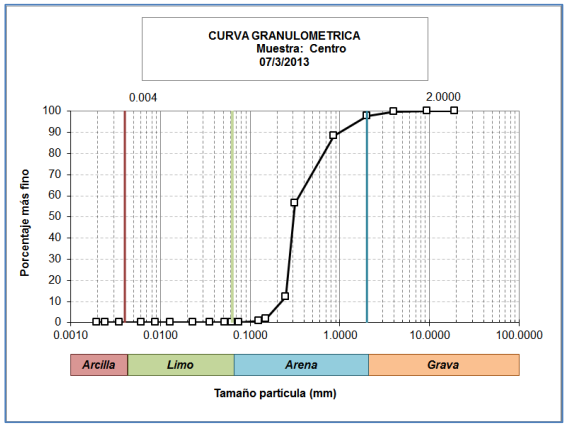


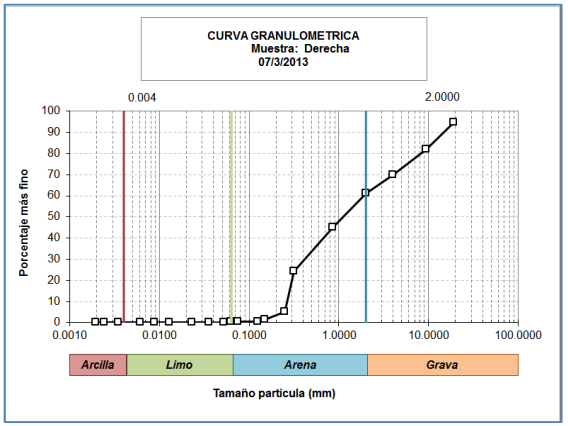




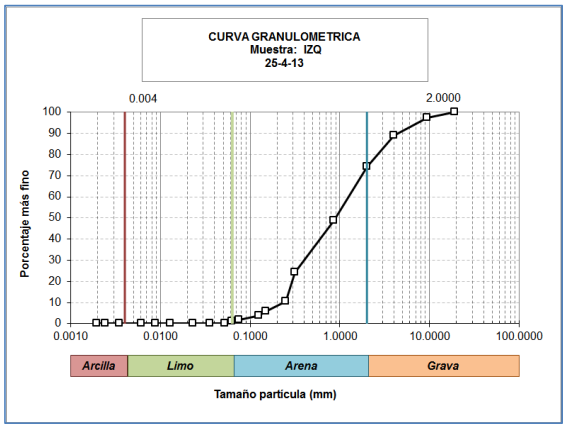
Mouth of San Carlos River
07 March 2013

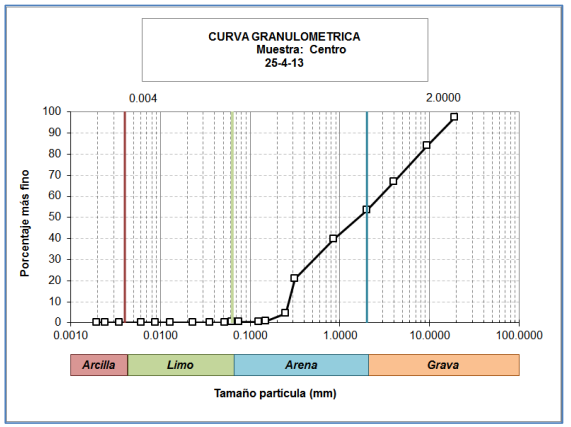


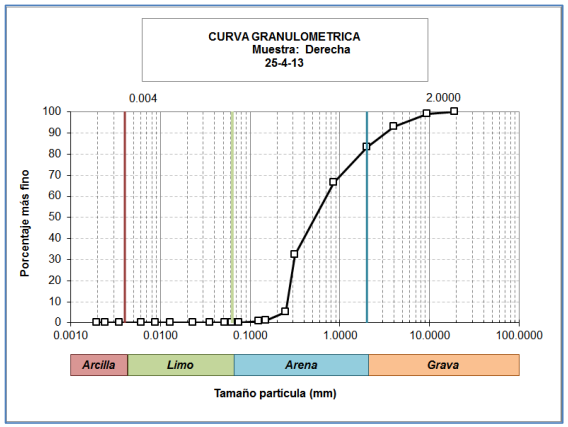




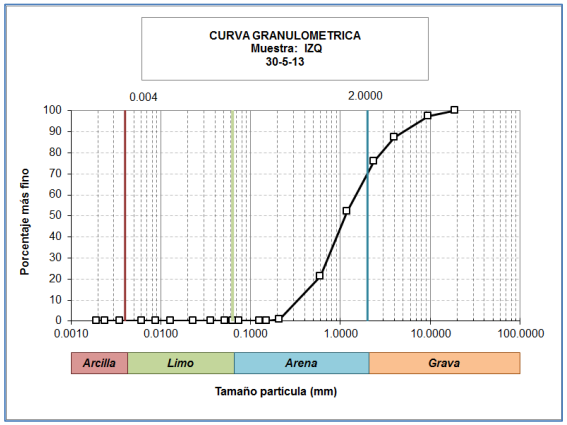
Mouth of San Carlos River
25 April 2013

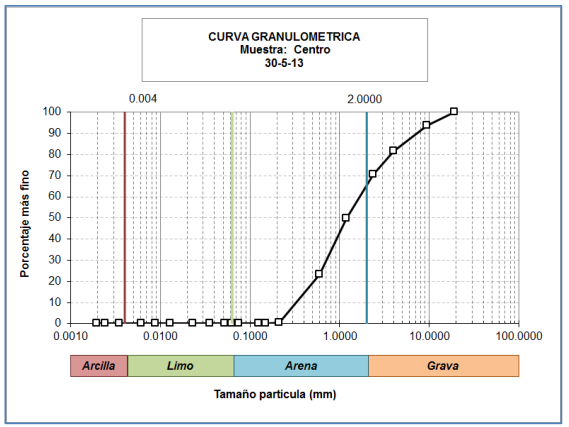


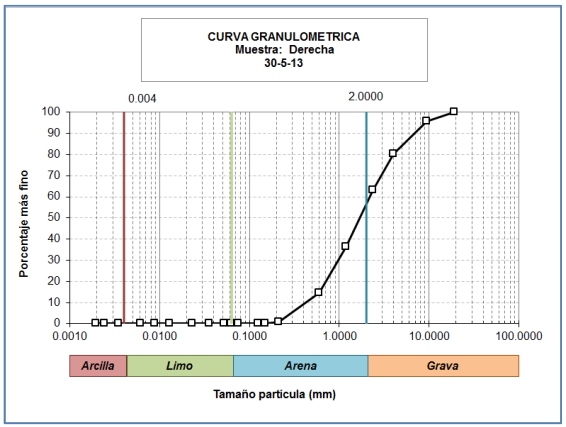




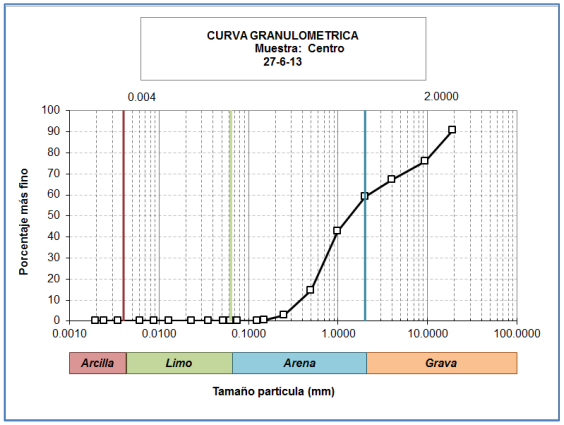
Mouth of San Carlos River
30 May 2013

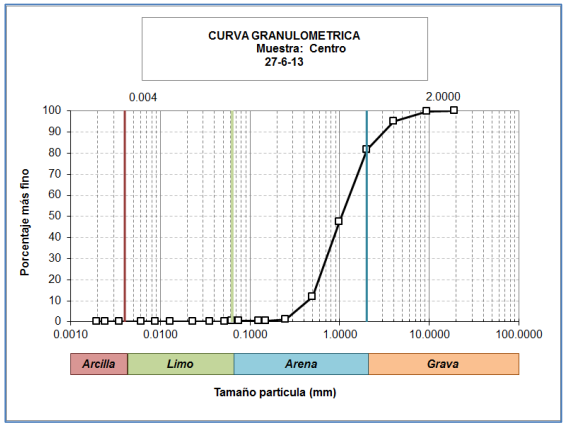


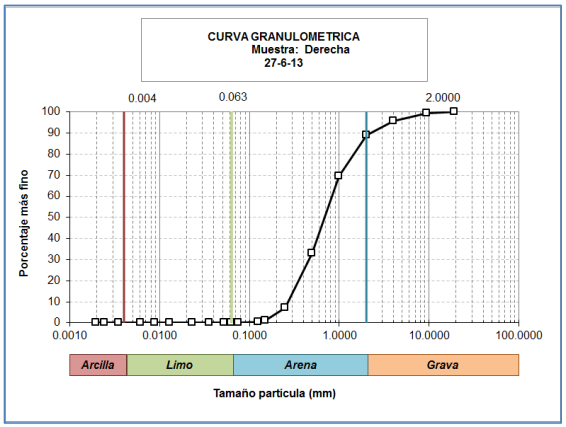




Mouth of San Carlos River
27 Jun 2013



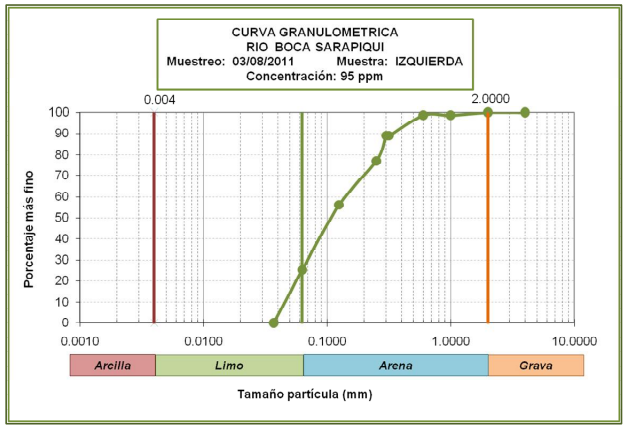


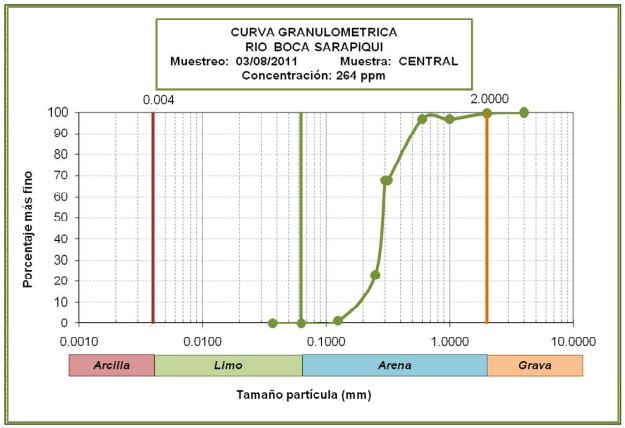


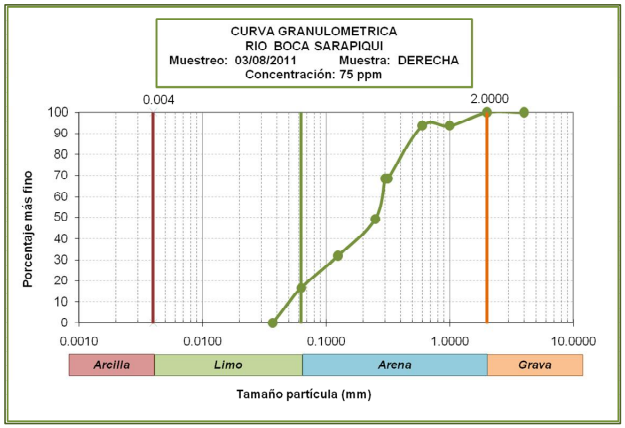
Bed-load sediment: Particle size distribution

Mouth of Sarapiquí River

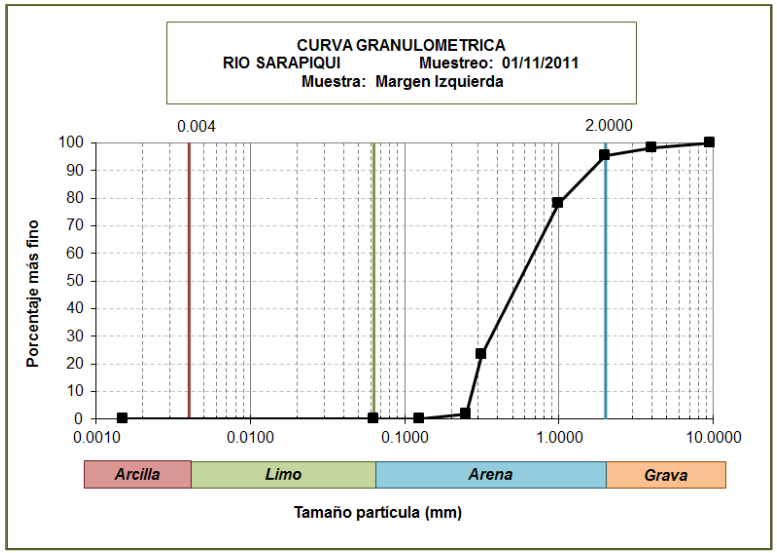
Mouth of Sarapiquí River
03 August 2011

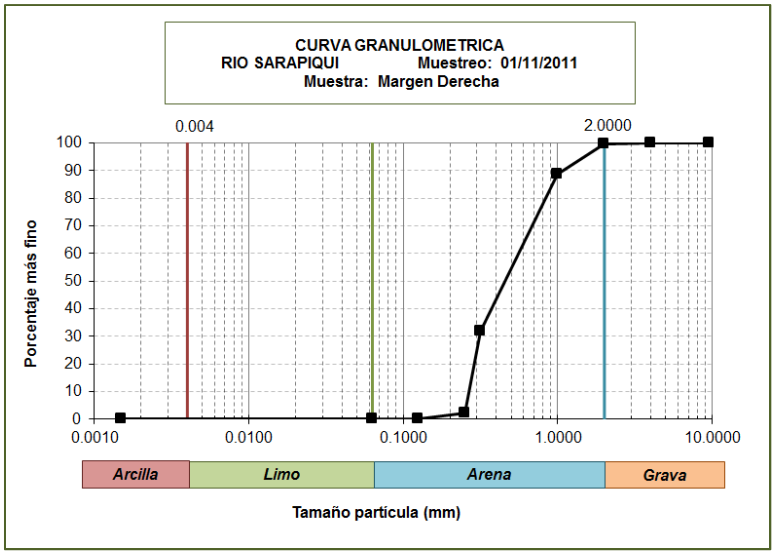




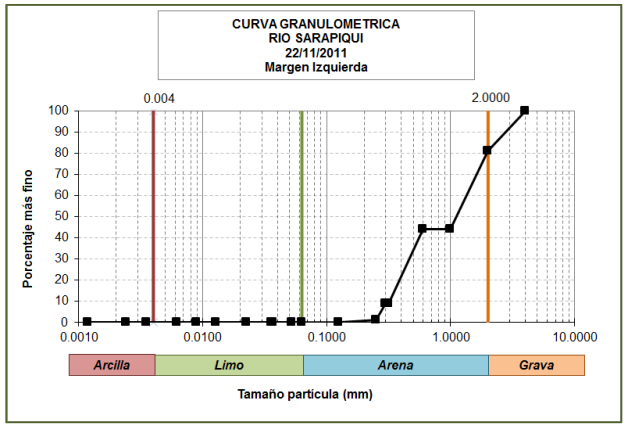


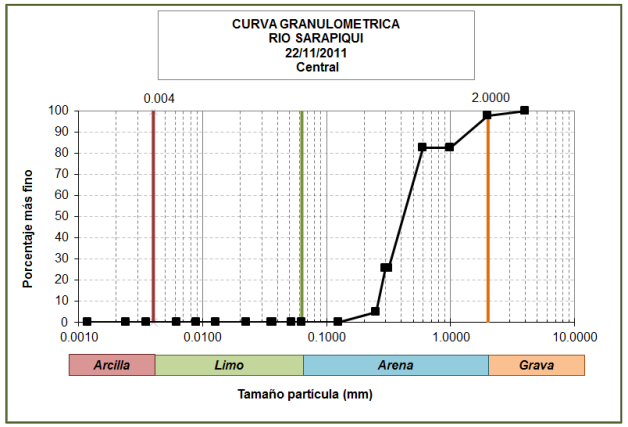
Mouth of Sarapiquí River
02 November 2011

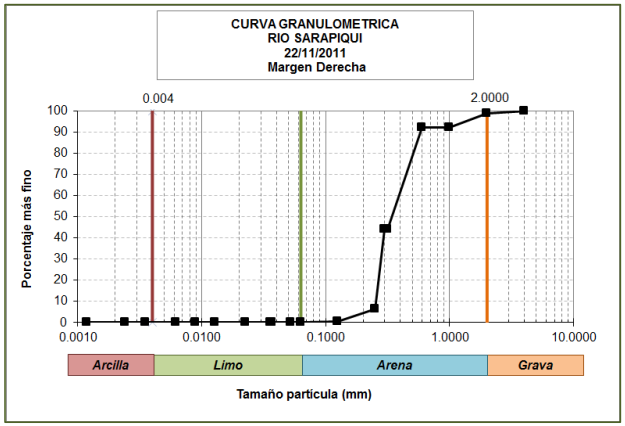




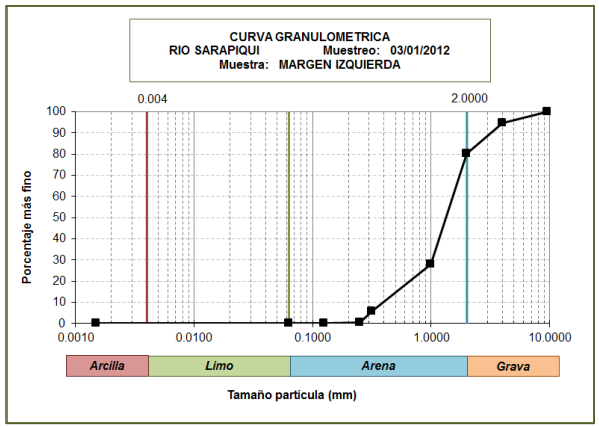
Mouth of Sarapiquí River
22 November 2011

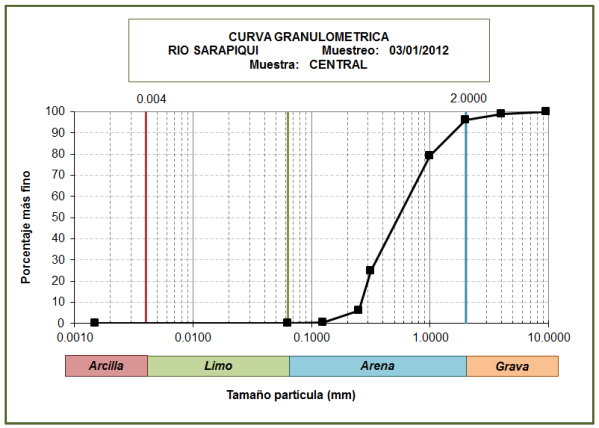


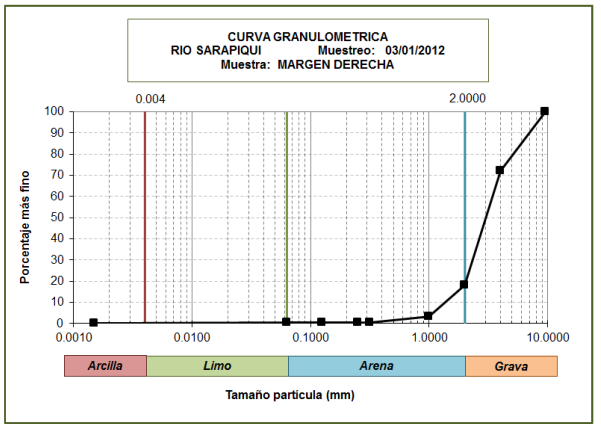




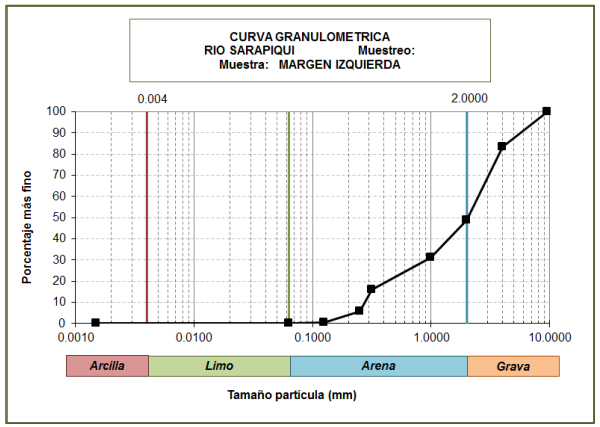
Mouth of Sarapiquí River
03 January 2012

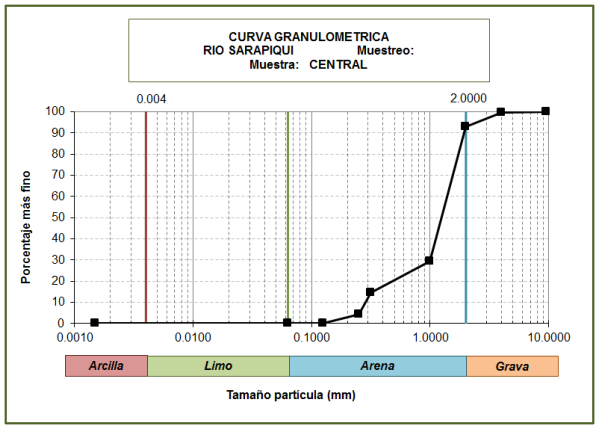


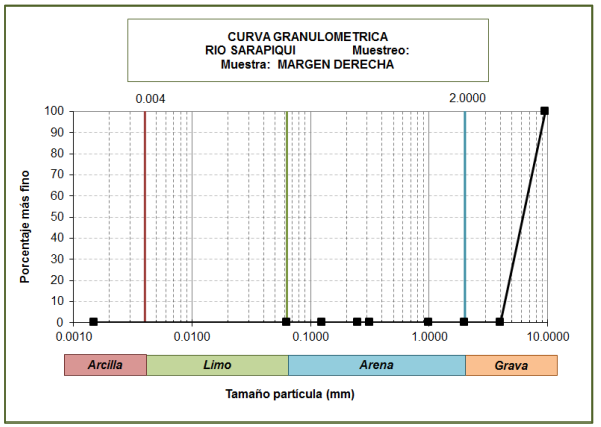




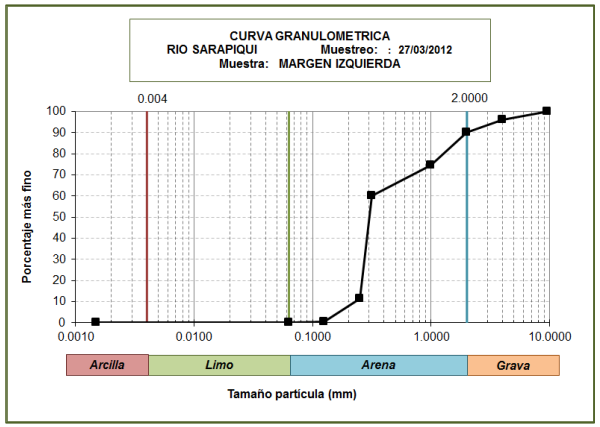
Mouth of Sarapiquí River
21 February 2012

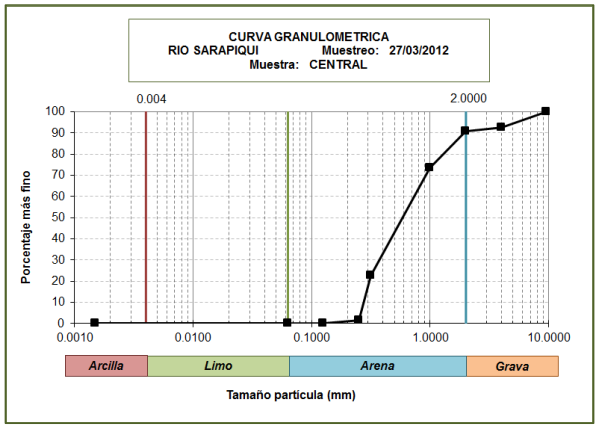


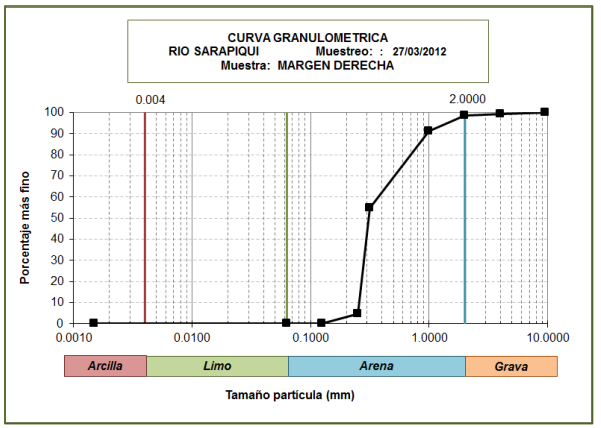




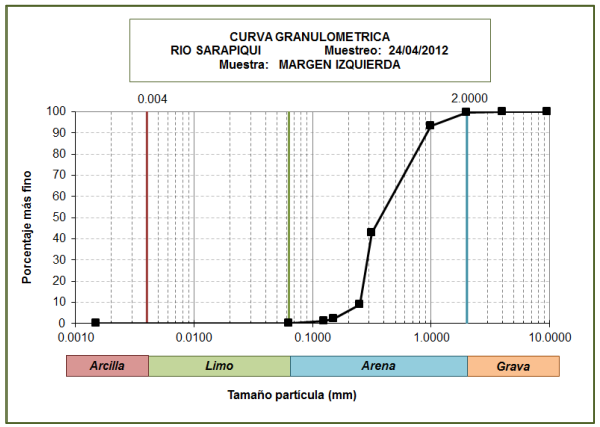
Mouth of Sarapiquí River
27 March 2012

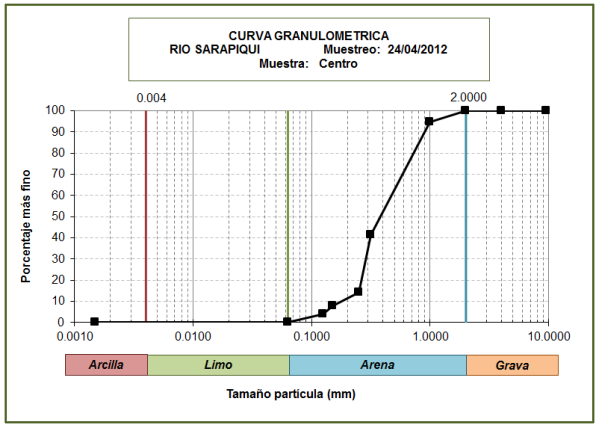


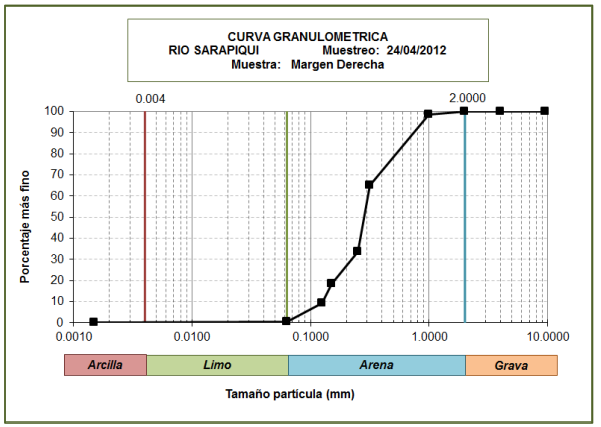




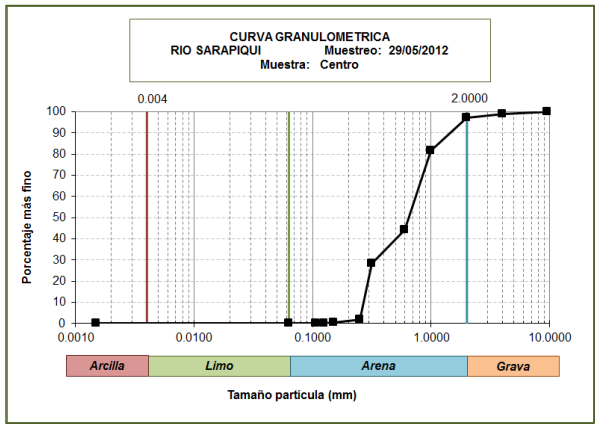
Mouth of Sarapiquí River
26 April 2012

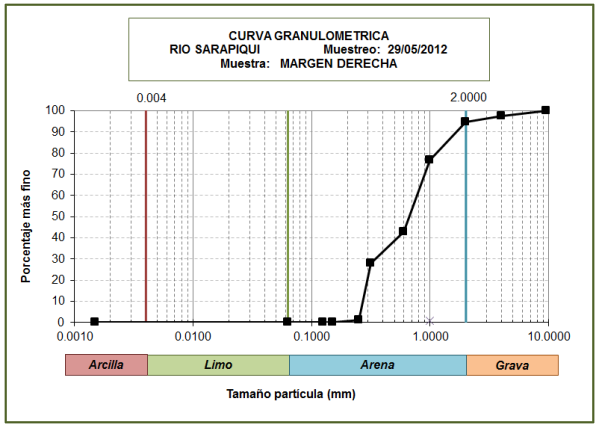


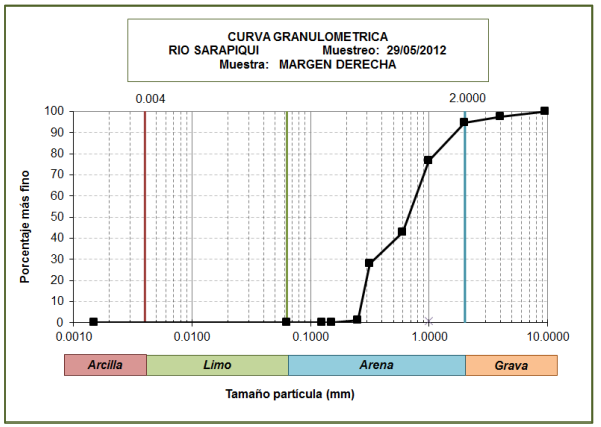




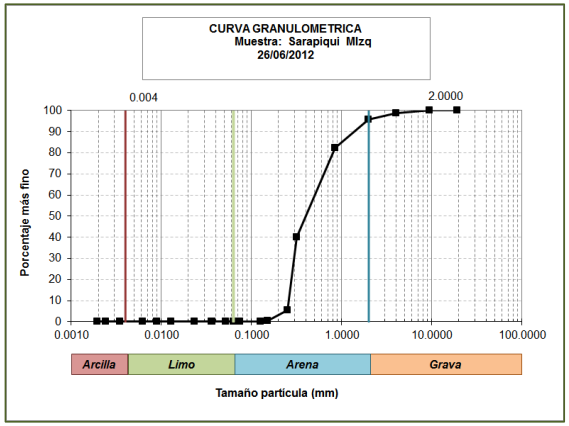
Mouth of Sarapiquí River
29 May 2012

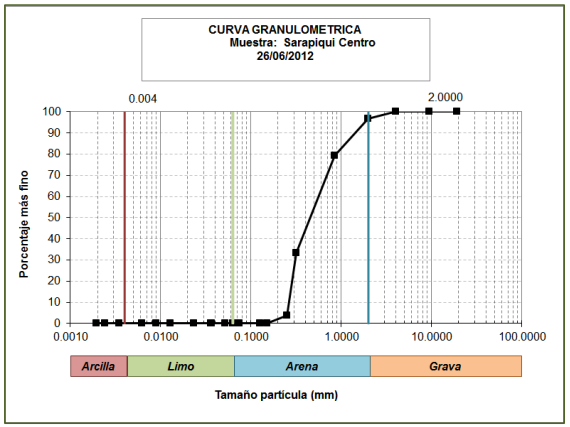


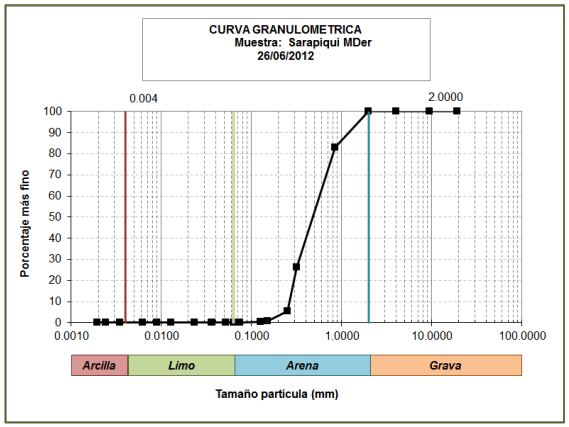




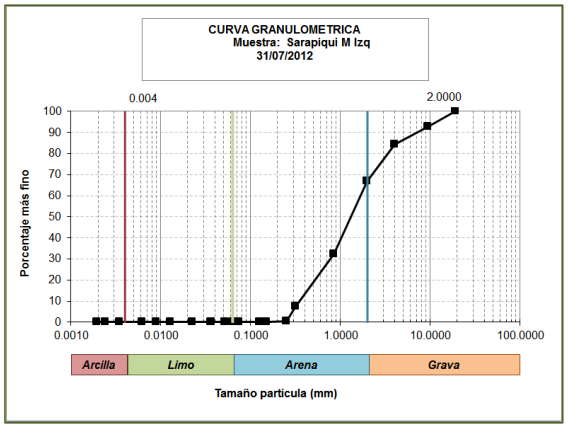
Mouth of Sarapiquí River
28 June 2012

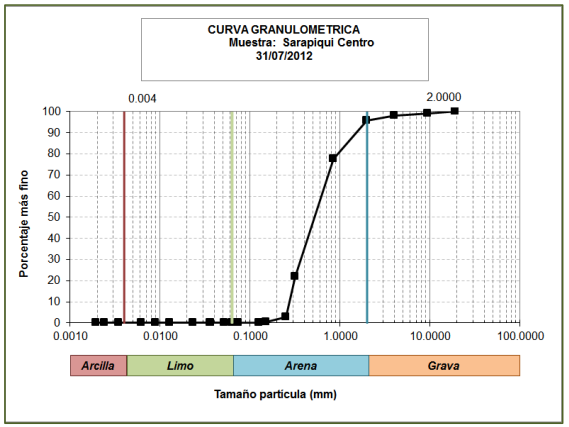


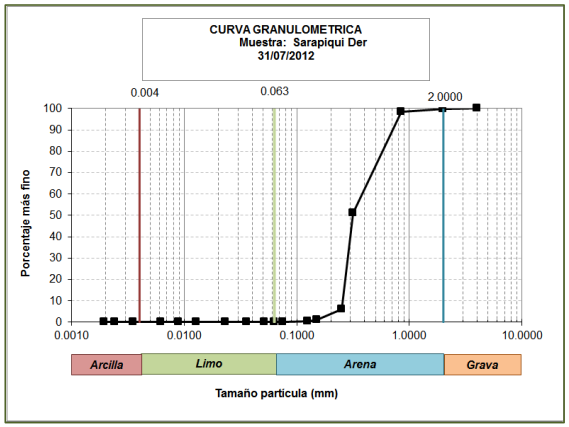




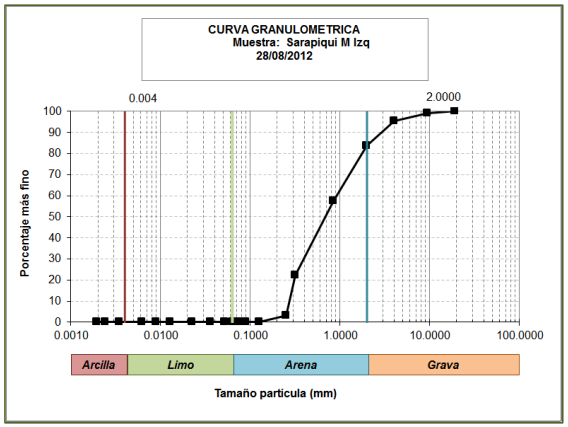
Mouth of Sarapiquí River
31 July 2012

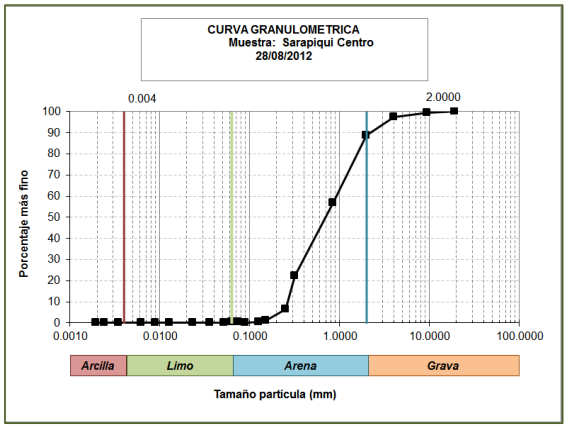


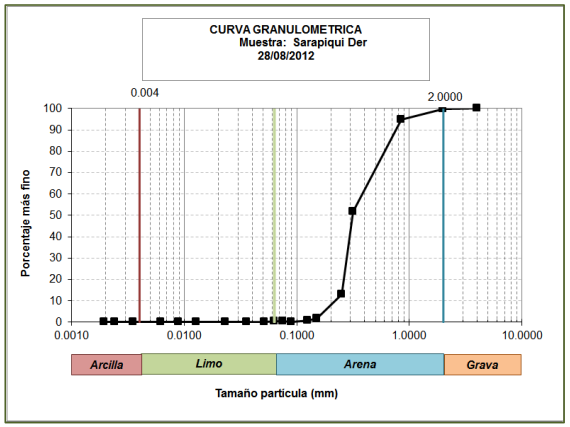




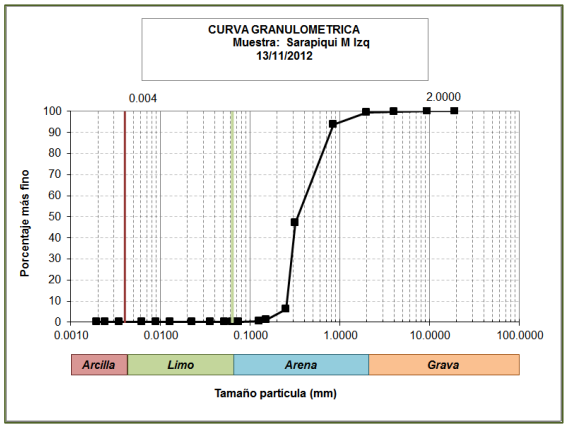
Mouth of Sarapiquí River
28 August 2012

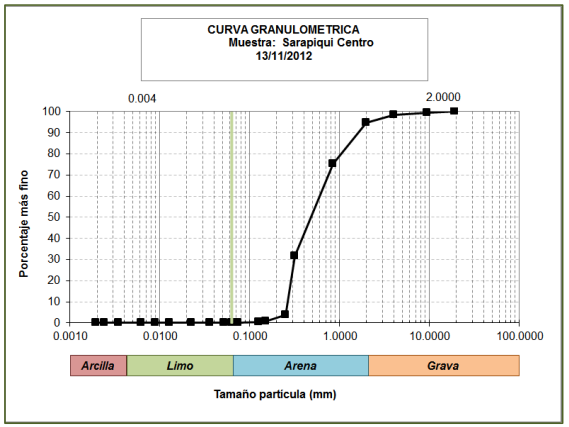


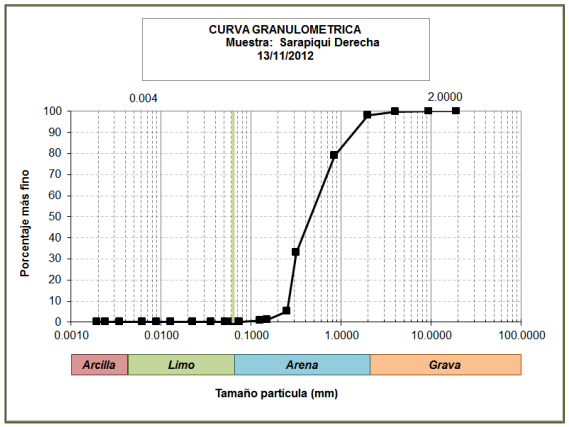




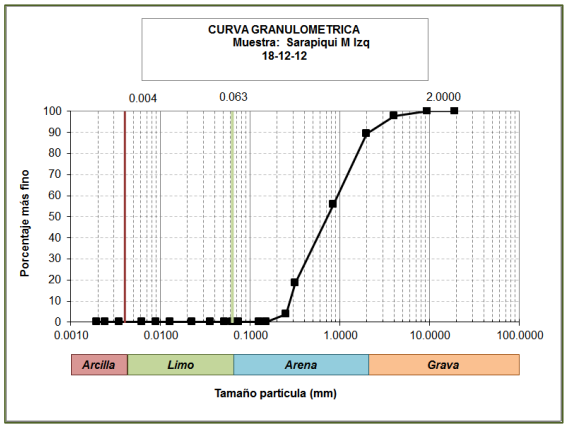
Mouth of Sarapiquí River
13 November 2012

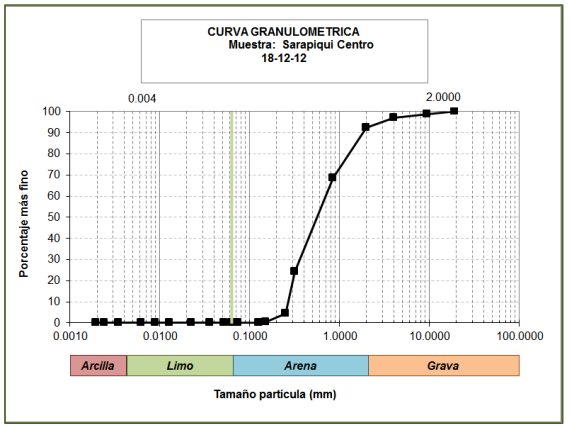


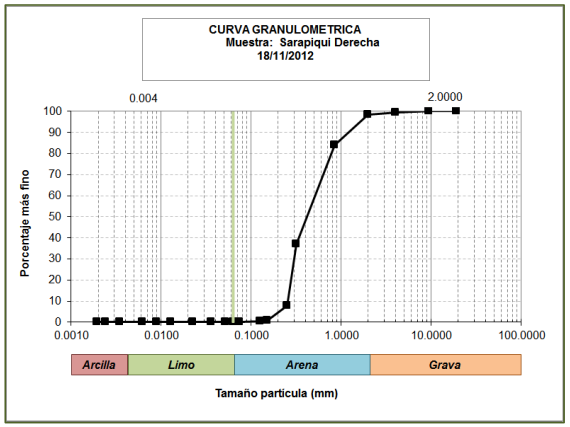




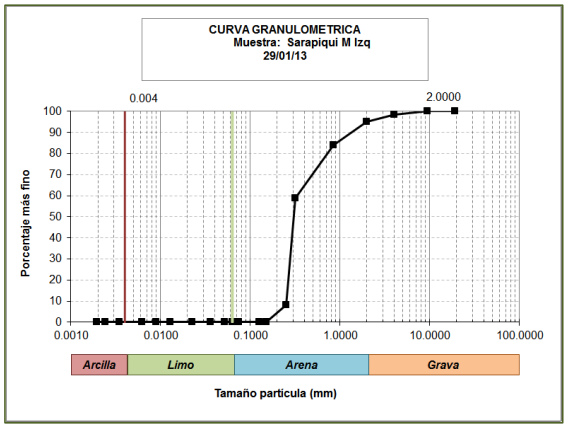
Mouth of Sarapiquí River
18 December 2012

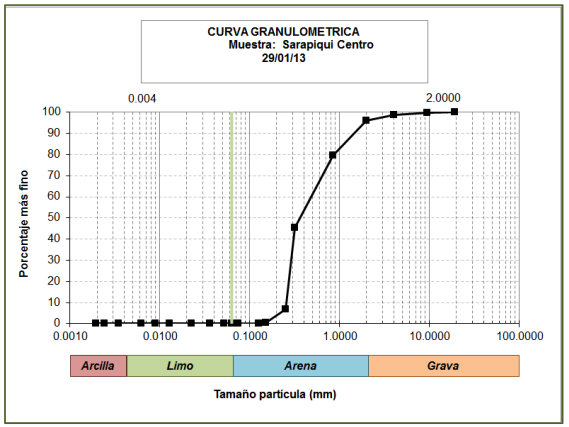


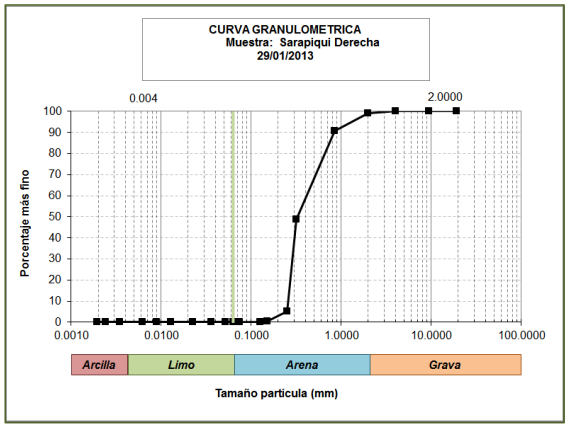




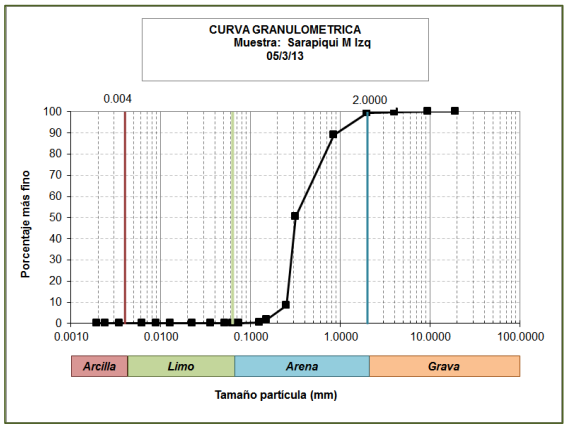
Mouth of Sarapiquí River
29 January 2013

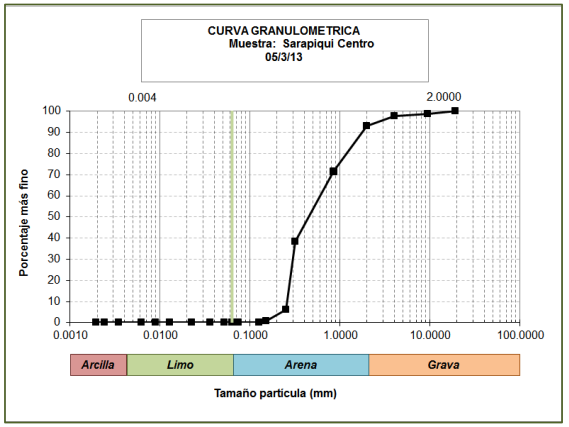


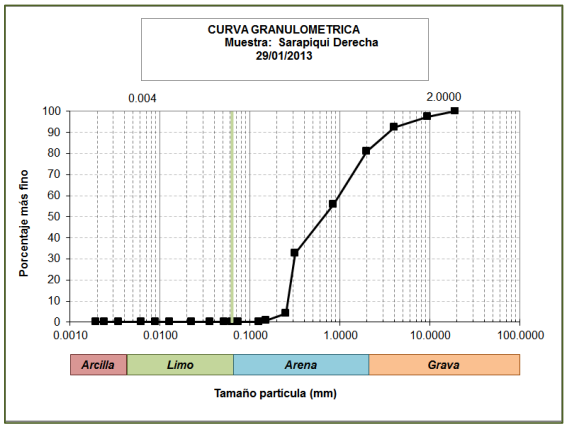




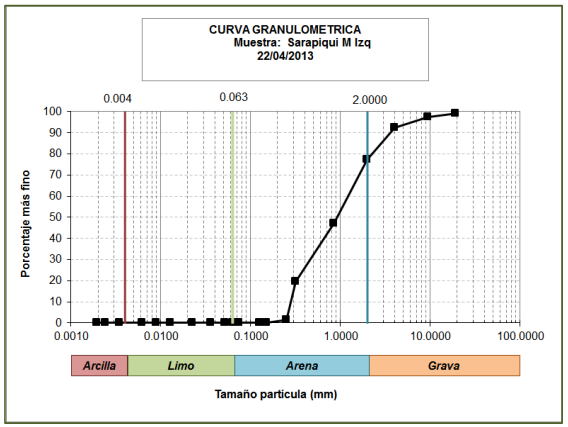
Mouth of Sarapiquí River
05 March 2013

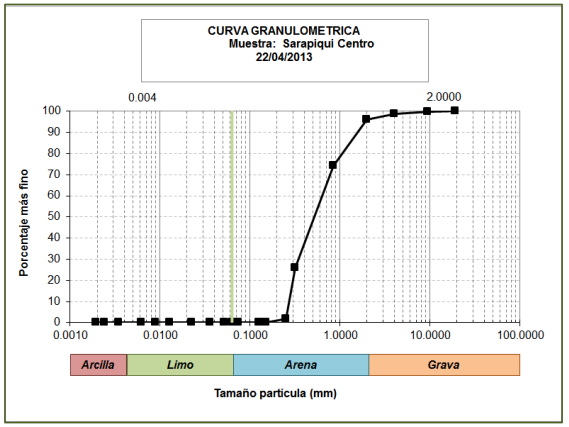


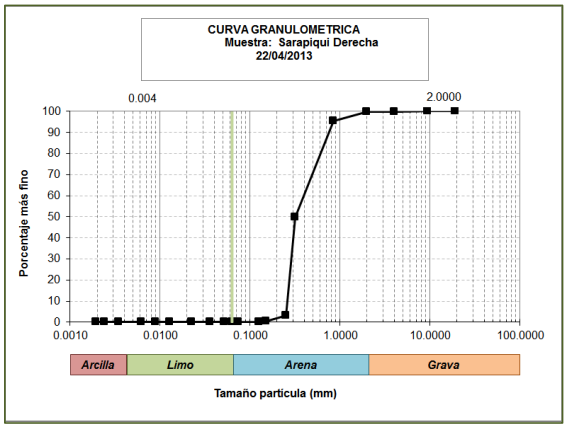




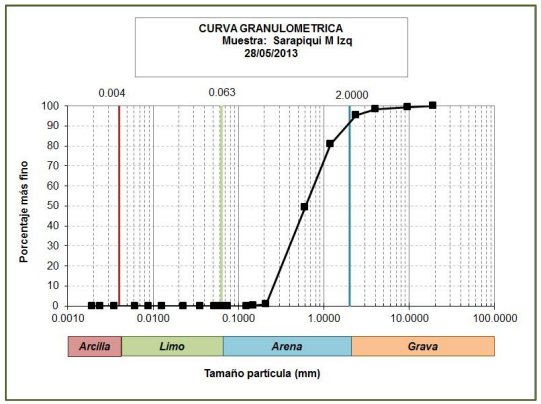
Mouth of Sarapiquí River
22 April 2013

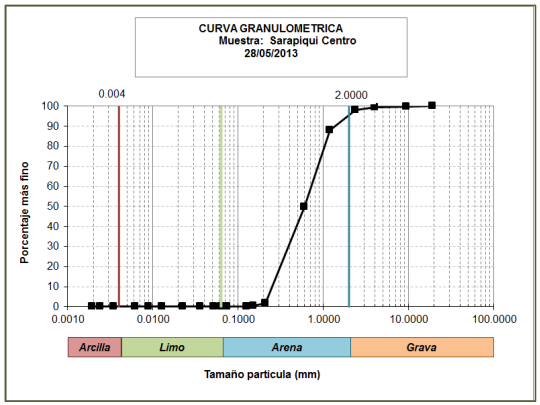


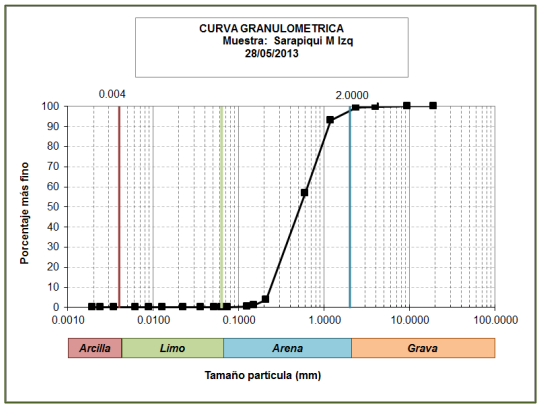




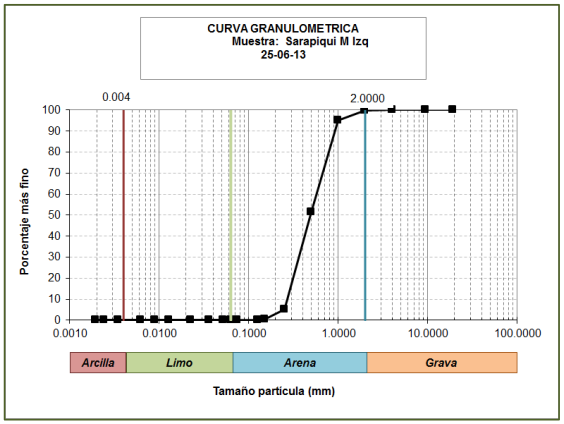
Mouth of Sarapiquí River
28 May 2013

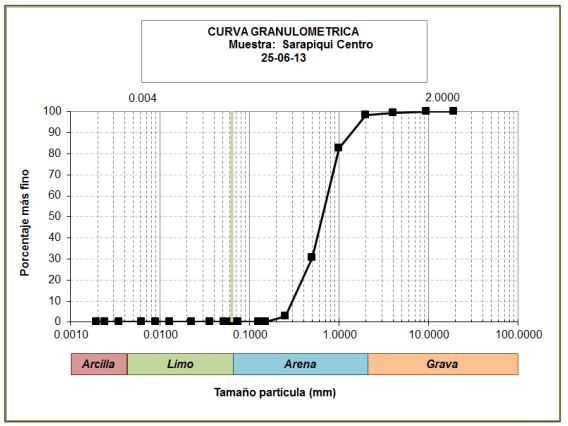


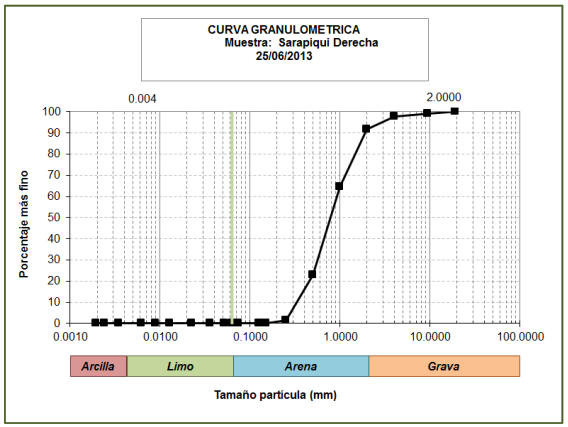




Mouth of Sarapiquí River
25 Jun 2013







APPENDIX F

DISTRIBUTIONS OF BOTH BED-LOAD MEDIAN GRAIN SIZE AND PERCENTAGE OF SAND, SAMPLED WITHIN THE PERIOD DECEMBER 2010 - JUNE 2013 AT DELTA COLORADO STATION (11-04)

Distribution of bed-load median grain size and percentage of sand at Delta Costa Rica

Hydrological station 11-04 (Delta Colorado). Samples from December 2010.

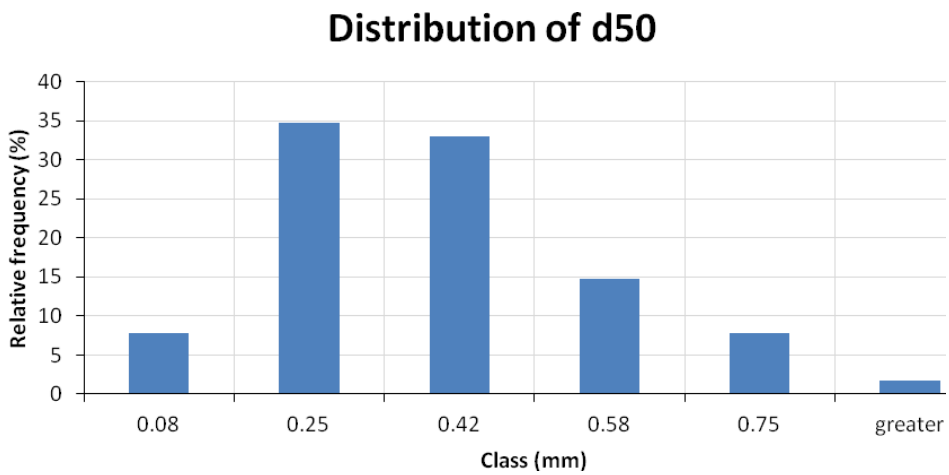
Sample	Date	d50 (mm)	% Sand
1	14/12/2010	0.10	60
2	14/12/2010	0.15	80
3	01/03/2011	0.25	100
4	01/03/2011	0.40	100
5	01/03/2011	0.65	100
6	01/03/2011	0.75	90
7	01/03/2011	0.70	90
8	03/03/2011	0.35	90
9	03/03/2011	0.50	90
10	03/03/2011	0.70	90
11	03/03/2011	0.70	90
12	03/03/2011	0.40	97
13	05/04/2011	0.30	100
14	05/04/2011	0.60	92
15	05/04/2011	0.65	95
16	05/04/2011	0.30	90
17	05/04/2011	0.75	80
18	06/07/2011	0.30	100
19	06/07/2011	0.50	85
20	06/07/2011	0.40	95
21	06/07/2011	0.35	100
22	06/07/2011	0.35	97
23	30/07/2011	0.40	90
24	30/07/2011	0.30	97
25	30/07/2011	0.40	95
26	30/07/2011	0.35	97
27	30/07/2011	0.35	92
28	30/07/2011	0.40	90
29	30/08/2011	0.35	87
30	30/08/2011	0.35	87
31	30/08/2011	0.55	92
32	05/10/2011	0.30	100
33	05/10/2011	0.30	100
34	05/10/2011	0.30	100
35	05/10/2011	0.40	100
36	03/11/2011	0.15	93
37	03/11/2011	0.30	100

Sample	Date	d50 (mm)	% Sand
38	03/11/2011	0.55	87
39	03/11/2011	0.30	100
40	03/11/2011	0.60	92
41	04/01/2012	2.00	22
42	04/01/2012	0.30	100
43	04/01/2012	0.65	87
44	04/01/2012	0.70	87
45	04/01/2012	0.65	97
46	30/01/2012	0.25	100
47	30/01/2012	0.35	92
48	30/01/2012	0.30	95
49	30/01/2012	0.30	100
50	30/01/2012	0.30	100
51	22/02/2012	0.35	90
52	22/02/2012	0.60	85
53	22/02/2012	0.55	67
54	22/02/2012	0.80	100
55	22/02/2012	0.70	80
56	06/03/2012	0.28	100
57	06/03/2012	0.55	87
58	06/03/2012	0.40	97
59	06/03/2012	0.40	90
60	06/03/2012	0.50	90
61	29/03/2012	0.55	95
62	29/03/2012	0.30	97
63	29/03/2012	0.30	100
64	29/03/2012	0.28	97
65	29/03/2012	0.09	68
66	25/04/2012	0.55	100
67	25/04/2012	0.45	92
68	25/04/2012	0.40	95
69	25/04/2012	0.28	97
70	25/04/2012	0.09	85
71	30/05/2012	0.09	80
72	30/05/2012	0.30	100
73	30/05/2012	0.25	92
74	30/05/2012	0.25	100
75	30/05/2012	0.10	100
76	27/06/2012	0.50	95
77	27/06/2012	0.30	100
78	27/06/2012	0.30	100

Sample	Date	d50 (mm)	% Sand
79	27/06/2012	0.08	75
80	27/06/2012	0.75	95
81	01/08/2012	0.25	100
82	01/08/2012	0.25	100
83	01/08/2012	0.30	100
84	01/08/2012	0.50	82
85	01/08/2012	0.18	95
86	29/08/2012	0.20	100
87	29/08/2012	0.25	100
88	29/08/2012	0.55	92
89	29/08/2012	0.50	92
90	29/08/2012	0.15	95
91	14/11/2012	0.30	95
92	14/11/2012	0.40	95
93	14/11/2012	0.28	100
94	14/11/2012	0.35	90
95	14/11/2012	0.50	90
96	19/12/2012	0.30	97
97	19/12/2012	0.30	100
98	19/12/2012	0.30	100
99	19/12/2012	0.30	100
100	19/12/2012	0.50	97
101	22/04/2013	0.50	82
102	22/04/2013	0.50	95
103	22/04/2013	0.40	95
104	22/04/2013	0.50	90
105	22/04/2013	0.28	100
106	28/05/2013	0.30	100
107	28/05/2013	0.45	100
108	28/05/2013	0.60	65
109	28/05/2013	0.60	82
110	28/05/2013	0.60	80
111	25/06/2013	0.45	97
112	25/06/2013	0.30	100
113	25/06/2013	0.40	97
114	25/06/2013	0.50	97
115	25/06/2013	0.90	90

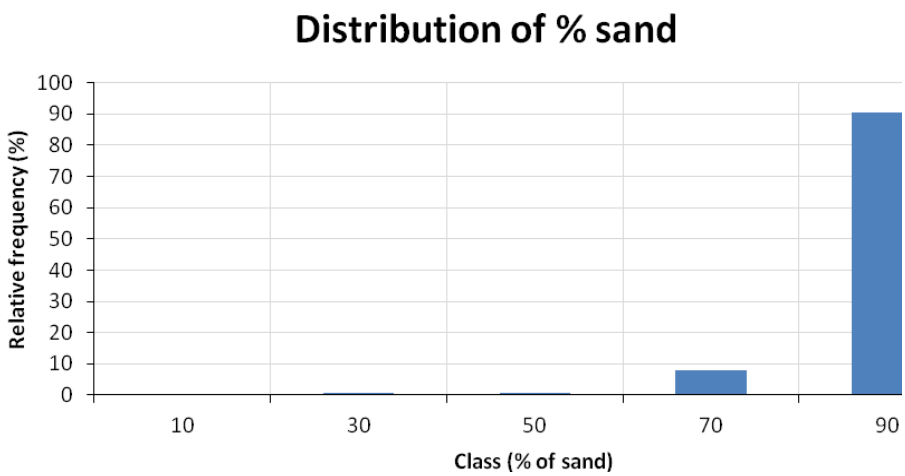
Frequency distribution of the median grain size (d_{50}):

Class	*Frequency*	*Relative frequenc (%)*
0.08	9	8
0.25	40	35
0.42	38	33
0.58	17	15
0.75	9	8
greater	2	2
Total	115	100



Frequency distribution of the percentage of sand (% Sand):

Class	*Frequency*	*Relative frequency (%)*
10	0	0
30	1	0
50	1	1
70	9	8
90r	104	90
Total	115	100



APPENDIX G

ESTIMATION OF THE ANNUAL BED-LOAD SEDIMENT ACCORDING TO THE EINSTEIN METHOD, FOR THE PERIOD 2010-2013 IN THE LOWER SAN JUAN AND COLORADO RIVERS

Refer to the two excel files submitted with this Report, entitled:

“ICE - 11 – Bedload – Einstein – Lower San Juan”; and

“ICE – 11 – Bedload – Einstein – Delta Colorado”.

APPENDIX H

H.1 FLOW DIAGRAM AND DESCRIPTION OF THE CALSITE MODEL

H.2 INPUT AND OUTPUT MAPS PRODUCED FOR THE DETERMINATION OF THE POTENTIAL EROSION AND SEDIMENT YIELD IN BOTH COSTA RICAN AND NICARAGUAN DRAINAGE BASINS

H.1 Flow diagram and description of the CALSITE model

Figure H.1 presents the flow diagram of the CALSITE model, and how each map interacts with the other in order to estimate soil erosion and sediment yield.

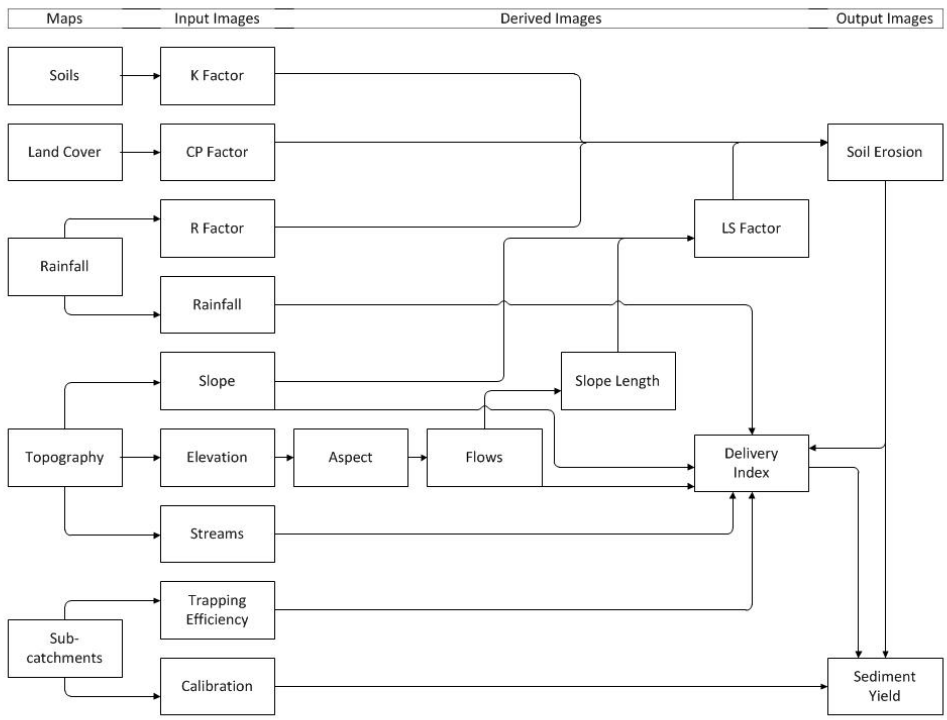


Figure H.1. Flow diagram of the CALSITE model.

Delivery index calculation

The delivery index (DI) is used to estimate delivery ratios (DR) for each area, where:

$$DR = \frac{Sediment\ at\ catchment\ outlet}{Total\ soil\ erosion}$$

The delivery index values are converted to delivery ratio ranging from 0 to 1, as part of the calibration procedure. The delivery index is defined as follows:

$$DI = \frac{Transport\ capacity}{Sediment\ supply}$$

Thus when transporting capacity is high but there is only a small sediment supply, the DI value es very high indicating that all the available sediment will be carried. When both, the transporting capacity and sediment supply, are high the DI values will

be intermediate in size as there may be insufficient transporting capacity to carry all the sediment. When the sediment supply is high and the transporting capacity is low the DI will be very low.

The equation used to determine the DI is defined based upon empirical studies by Amphlet and Dickinson (1989); and laboratory studies by Govers (1990).

$$DI = \frac{{P_a}^{2.32} \cdot \min\{F^{0.66} S^{1.44}\}}{SE}$$

Where:

SE = soil erosion,

Pa = annual rainfall in mm

F = number of converging flow paths

S = slopein degrees

Min = minimum value down flowpath

The calibration procedure

The calibration of sediment yield (SY) is based upon the assumption that in the equation:

$$SY = SE \cdot DR$$

The calibration routine therefore manipulates de DR values over the study area until a good fit between observed and predicted sediment yield values is obtained. First calculate the DI then converted to DR values by calibration routine.

For obtaining the sediment delivery function, it is assumed that the eroded material has a single grain size because a single threshold has been taken. The eroding material will consist of size fractions spacing many orders of magnitude. Thus, while the threshold may be exceeded for the finest materials and DR will be unity, the coarse material will have much lower transporting capacities which may limit the quantity of material reaching the stream network.

The sediment delivery function is made with a single grain size will be translated into a curve with another shape. The shape has been derived by making the following two assumptions: (a) the material being eroded has an even distribution of settling velocity covering fine orders of magnitude, which is equivalent to material ranging from clay to sand of size about 1mm; (b) the transporting capacity of the flow is inversely proportional to settling velocity as implied by Westrich and Jurashek (1985).

H.2 Input and output maps

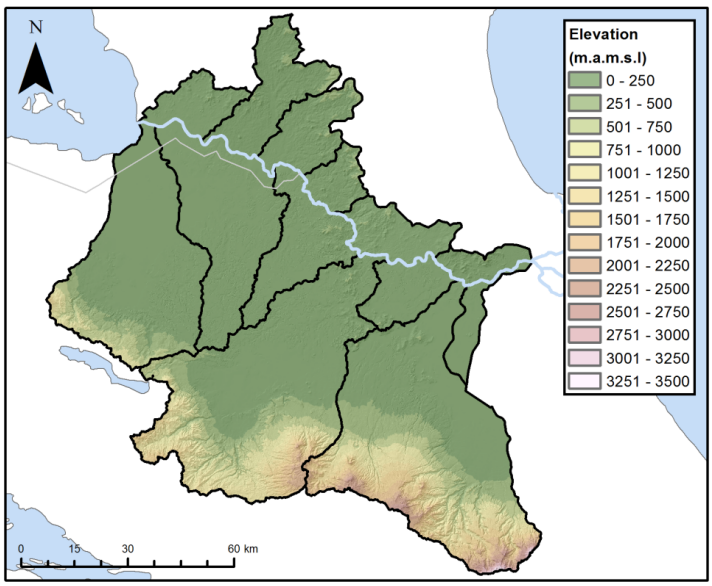


Figure H.2. Digital elevation model of Costa Rican and Nicaraguan main river basins draining to the San Juan River.

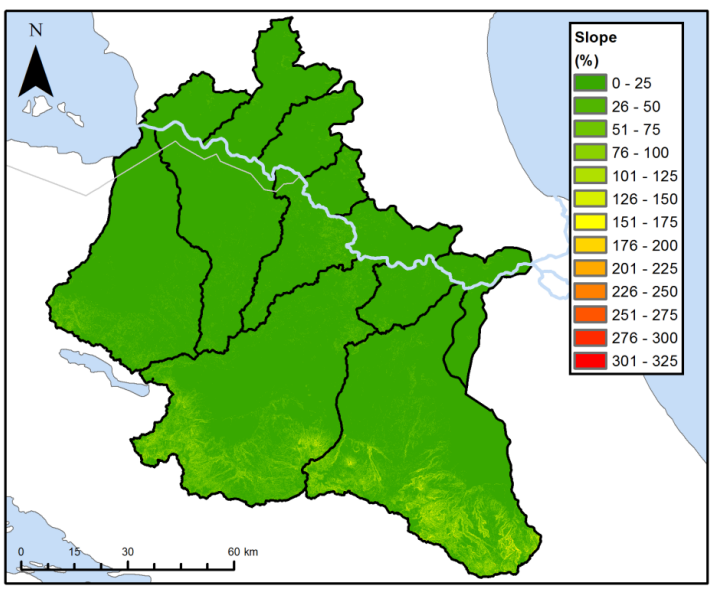


Figura H.3. Slope map for Costa Rican and Nicaraguan main river basins draining to the San Juan River.

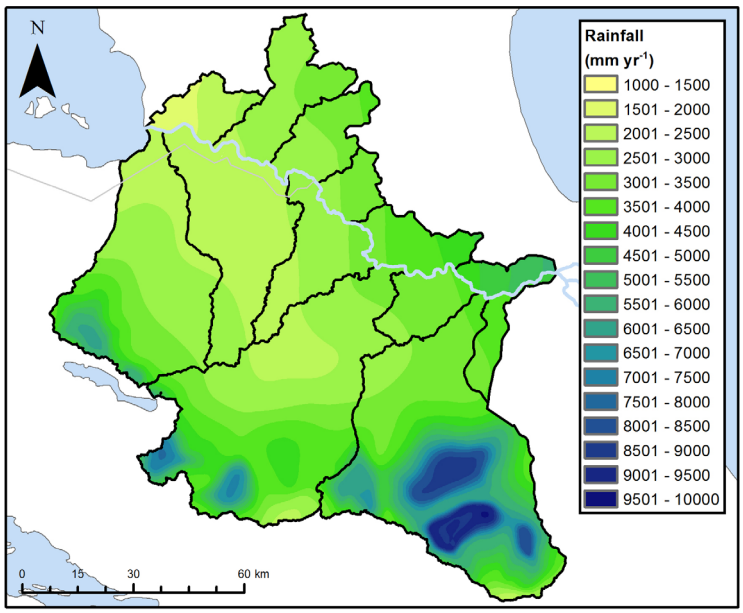


Figura H.4. Mean annual rainfall map for Costa Rican and Nicaraguan main river basins draining to the San Juan River.

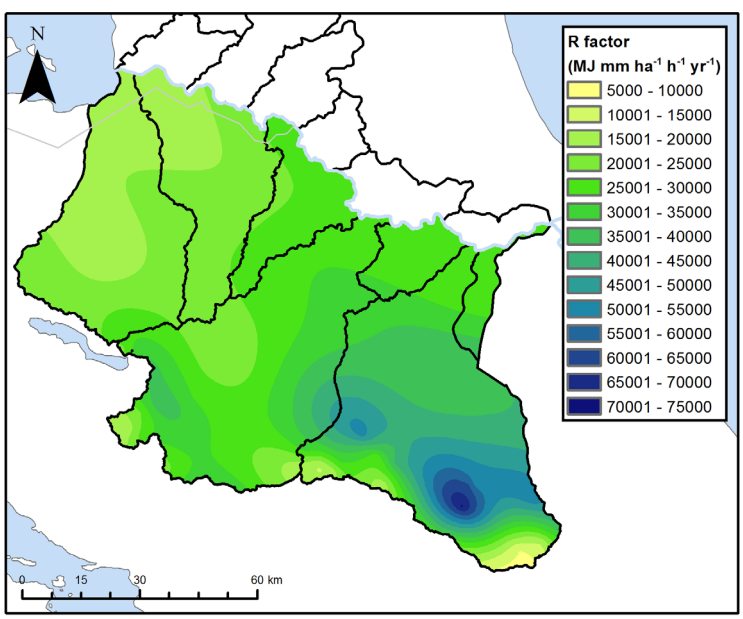


Figura H.5. R factor map for Costa Rican main basins draining to the San Juan River.

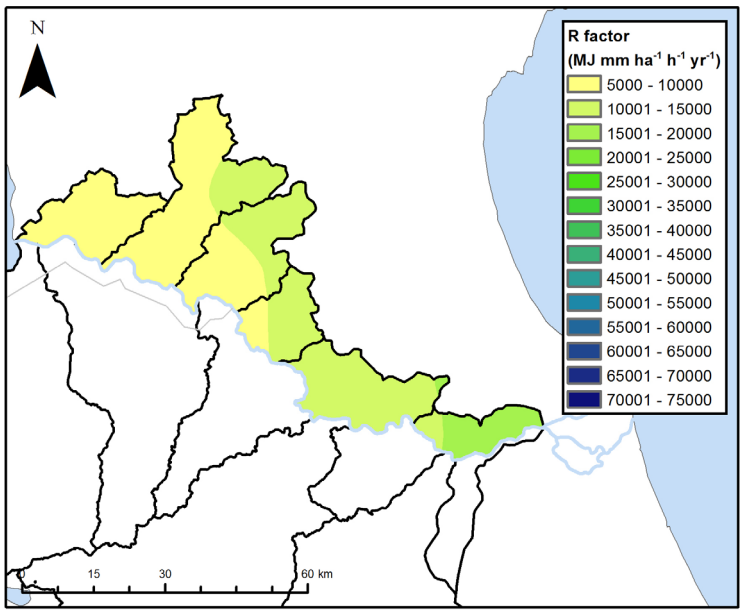


Figura H.6. R factor map for Nicaraguan main basins training to the San Juan River.

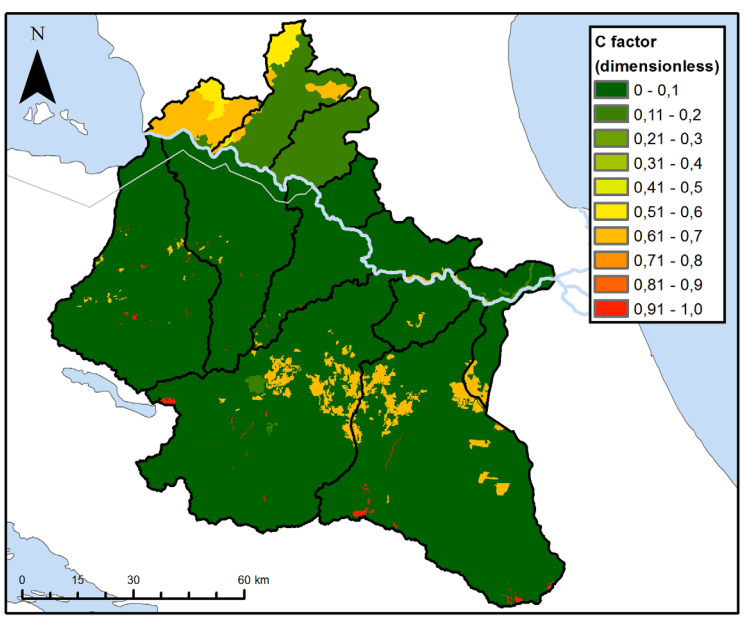


Figura H.7. C factor map for Costa Rican and Nicaraguan main river basins draining to the San Juan River.

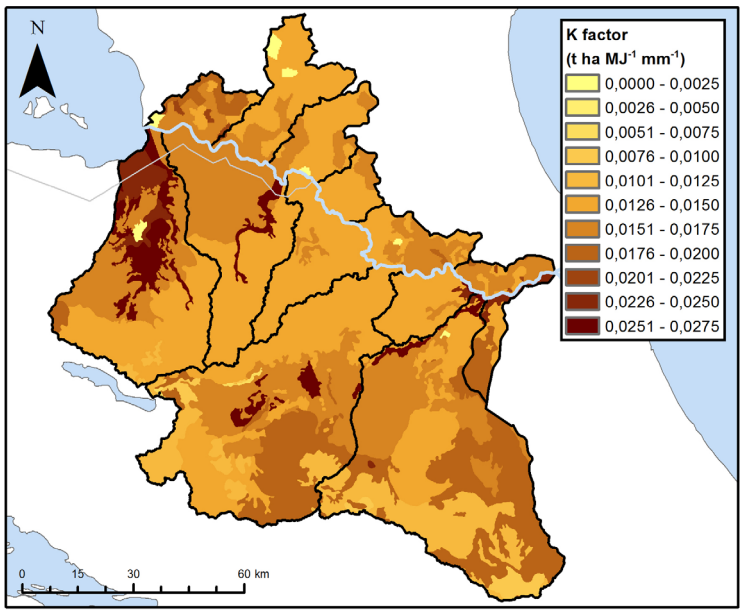


Figura H.8. K factor map for Costa Rican and Nicaraguan main river basins draining to the San Juan River.

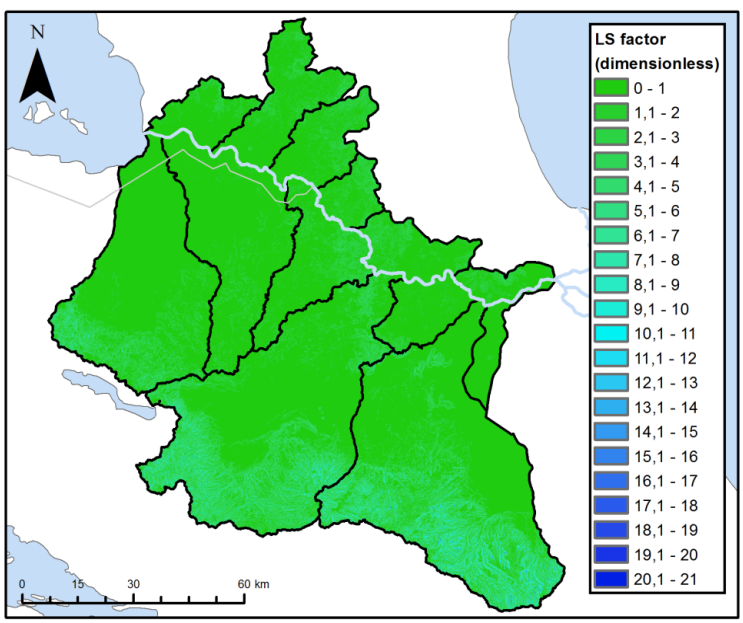


Figura H.9. LS factor map for Costa Rican and Nicaraguan main river basins draining to the San Juan River.

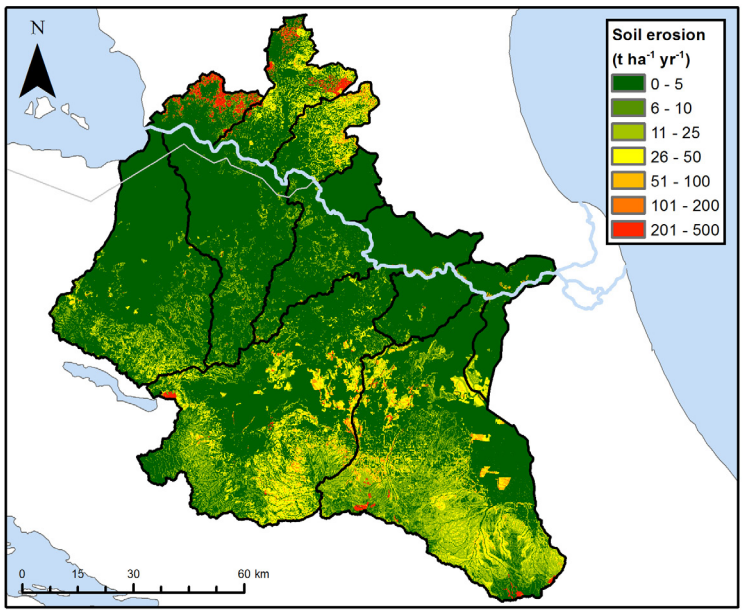


Figura H.10. Potential erosion map for Costa Rican and Nicaraguan main river basins draining to the San Juan River.

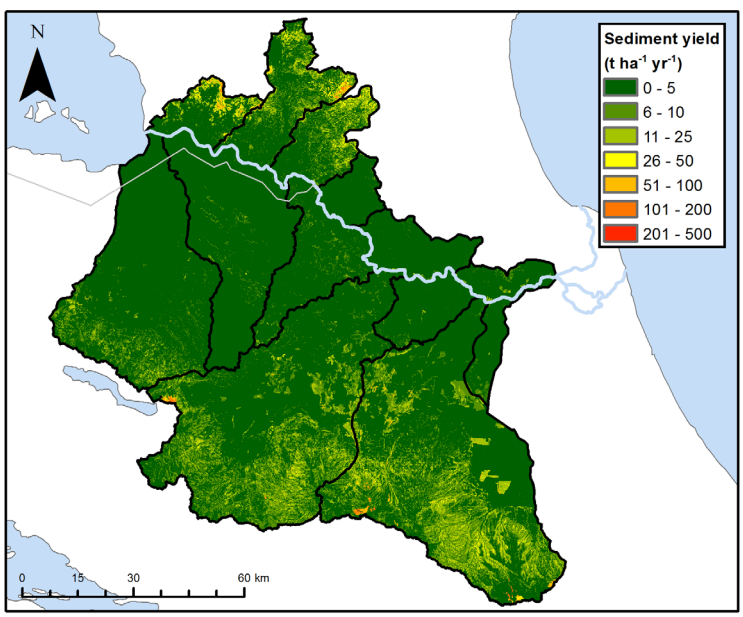
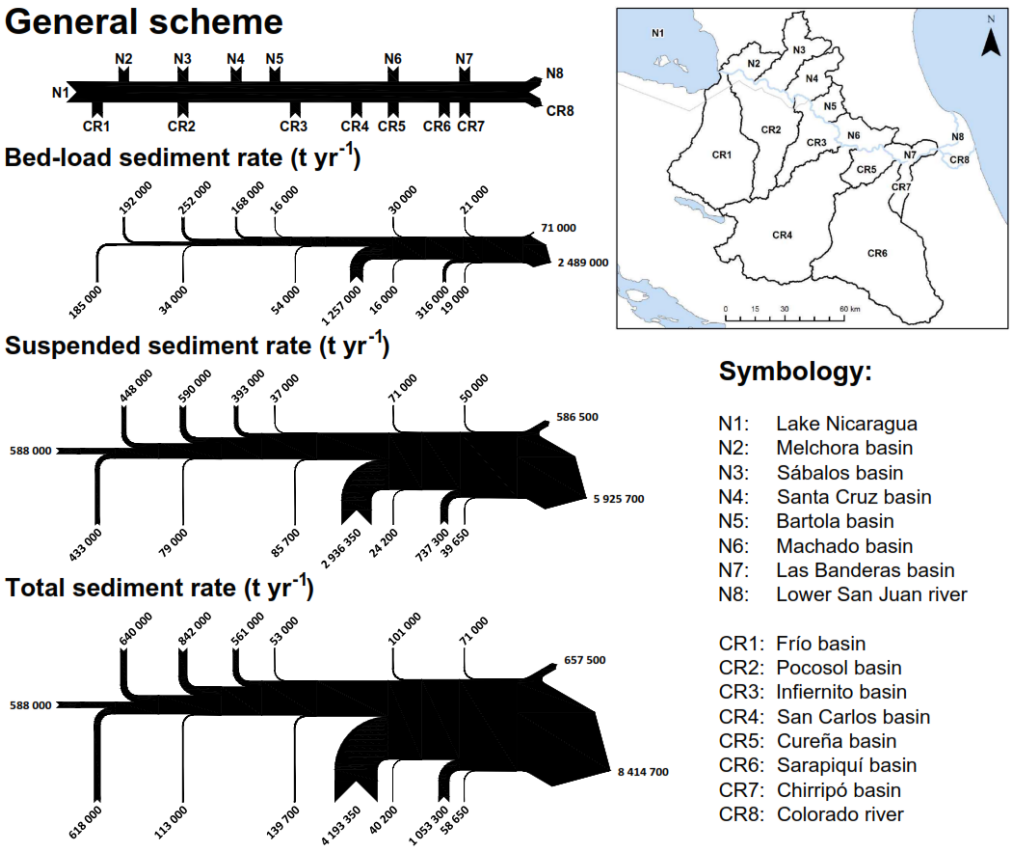


Figura H.11. Specific sediment yield map for Costa Rican and Nicaraguan main river basins draining to the San Juan River.

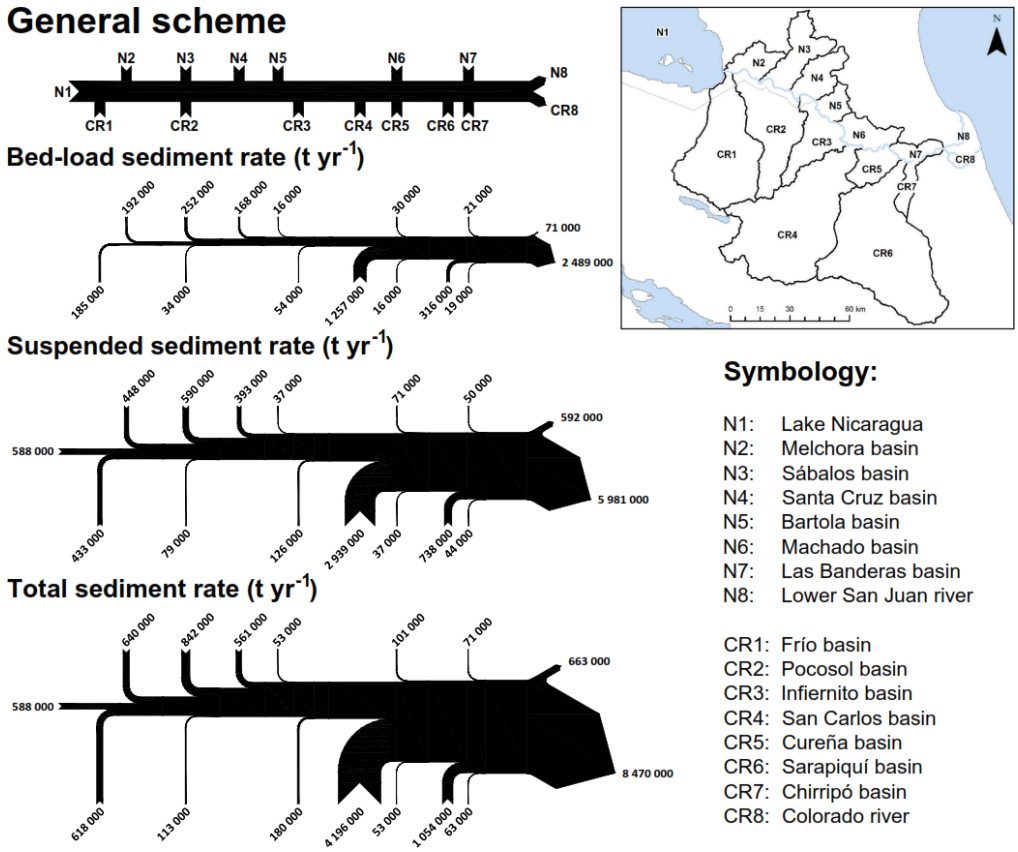
APPENDIX I

DISAGGREGATED DIAGRAMS, BY SEDIMENT LOAD COMPONENT, OF THE SEDIMENT BALANCE IN THE SAN JUAN - COLORADO RIVER SYSTEM, BEFORE AND AFTER ROUTE 1856 CONSTRUCTION

I.1. Sediment balance by load component, in the San Juan - Colorado River system, before the construction of Route 1856



I.2. Sediment balance by load component, in the San Juan - Colorado River system, after the construction of Route 1856



ANNEX 5

Dr. Andreas Mende with Dr. Allan Astorga and Dr. Olivier Chassot

Border Road No. 1856 – Evaluation of the 54 sites of Purported Direct Sediment Delivery mentioned by Ph.D. Mathias Kondolf

September 2013

Border Road Nº 1856 – Evaluation of the 54 Sites of Purported Direct Sediment Delivery mentioned by Ph.D. Mathias Kondolf

Elaborated by:

Dr. Andreas Mende
International Expert in Geographic Information Systems and Remote Sensing

In Collaboration with:

Dr. Allan Astorga
International Expert in Environmental Geology and Land Management

Dr. Olivier Chassot
General Manager of the Tropical Science Centre

Presented to:

Ministry of Foreign Affairs

Government of Costa Rica

San José - Costa Rica
September 2013

1 INTRODUCTION

In their analysis of environmental damages related to the construction of the border road Nº 1856 along the frontier between Costa Rica and Nicaragua, Dr. Mathias Kondolf and his colleagues presented 54 sites where they claim there is direct flow of sediment from the border road into the San Juan River (Kondolf et al., 2012) (hereinafter "the Kondolf Report").

The aim of this report is to carry out a detailed analysis of all those 54 points mentioned by the Kondolf Report based upon field work, helicopter flights and navigations on the San Juan River, in order to verify whether there can be found any indicators to confirm or deny Dr. Kondolf's statement regarding each of those 54 sites. For this task, the coordinates provided by Nicaragua to Costa Rica were used as reference of the location of the sites.

In another study we present an inventory of all water courses and slopes related to the construction of the border road Nº 1856, including an estimation of the quantity of sediment produced by each of those slopes per year (Mende et al., 2013). Based on these data we present an estimation about the maximum quantity of sediment which could reach the San Juan River per year at each of the sites mentioned by the Kondolf Report. This was calculated by adding up the values of sediment production of all slopes with potential drainage to the corresponding sites listed by Dr. Kondolf. It is important to mention that these numbers represent the worst case scenario because only under extraordinary circumstances all of the produced sediment would reach the San Juan River.

It must be noted that 7 of the sites mentioned by the Kondolf Report are actually located on Nicaraguan territory. Therefore, those sites have been assigned a 0 value for sediment input because there is no sediment delivery coming from Costa Rica to the San Juan River from them. This does not preclude that those sites may contribute sediment to the San Juan River, but this was not possible to assess because we were unable to undertake field work on the Nicaraguan territory. In the case of two Kondolf sites (Nº 36 and 49) erosive water courses have been found which produce certain amounts of sediment being transported to the San Juan River. In these cases it is not possible to estimate the maximum sediment production because the measurement of the volume eroded by a specific water course would require a complex analysis which has not been possible to execute in the frame of this study.

In order to have a well-founded base to assign proportional values of maximum sediment input to the San Juan River, we compare the absolute values of estimated sediment production with the total sediment load transported by the San Juan River at each of the 54 sites listed by Dr. Kondolf. This information has been extracted from the hydrological model of the San Juan River System carried out by the "Instituto Costarricense de Electricidad - ICE" under the leadership of Dr. Federico Gomez-Delgado

(Gomez-Delgado, 2013). The percentage value of the maximum sediment input induced by the border road at a specific site listed by Kondolf in relation to the total sediment transported by the San Juan River at this point gives a reasonable basis to estimate whether any of the 54 sites has the actual potential to produce any damage to this river system.

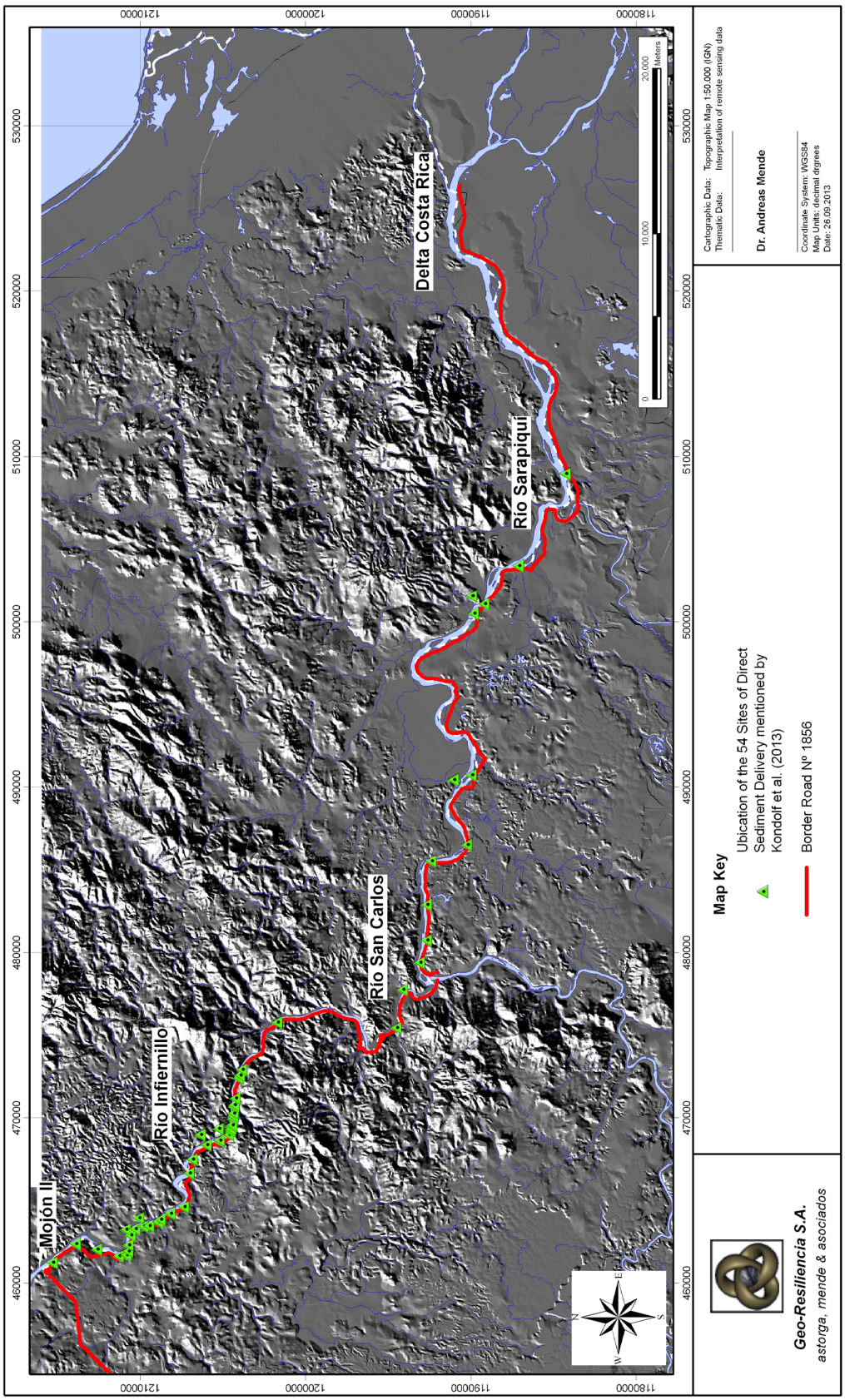
This report contains two main parts. The first part comprises an overview map exhibiting the spatial distribution of the 54 sites mentioned by the Kondolf Report as well as a set of 13 detail maps showing the local conditions of those sites. The detail maps are based upon a land use map elaborated by Astorga & Mende (2013) and also contain the spatial distribution of water courses and slopes along the border road Nº 1856 (Mende & Astorga, 2013).

The second part of this Report contains a data sheet for each of the 54 locations specified in the Kondolf Report in order to give a sound basis of information about their local conditions. These data sheets contain the following information:

1. GPS – Coordinates of the site given in decimal degree units as presented by the government of Nicaragua to the International Court of Justice on July 2013 (Annex I from the note HOL-CAG-146 dated 29 of July 2013).
2. Estimation of the Maximum Sediment Production at the site based upon the inventory of slopes (Mende et al., 2013).
3. Sediment transported at the site in the San Juan River, derived from the hydrological model of the San Juan River (Gomez-Delgado et al., 2013).
4. Percentage of the Maximum Sediment Production versus Total Sediment Flow in the San Juan River.
5. A short description of the specific characteristics of the site.
6. Reference to the ID codes of slopes and water courses as included within the inventory of water courses and slopes of the Border Road Nº 1856 (Mende et al., 2013).
7. A detail map showing the local conditions of the site.
8. Representative photographs of the site in order to provide direct visual information about the actual situation at the site.

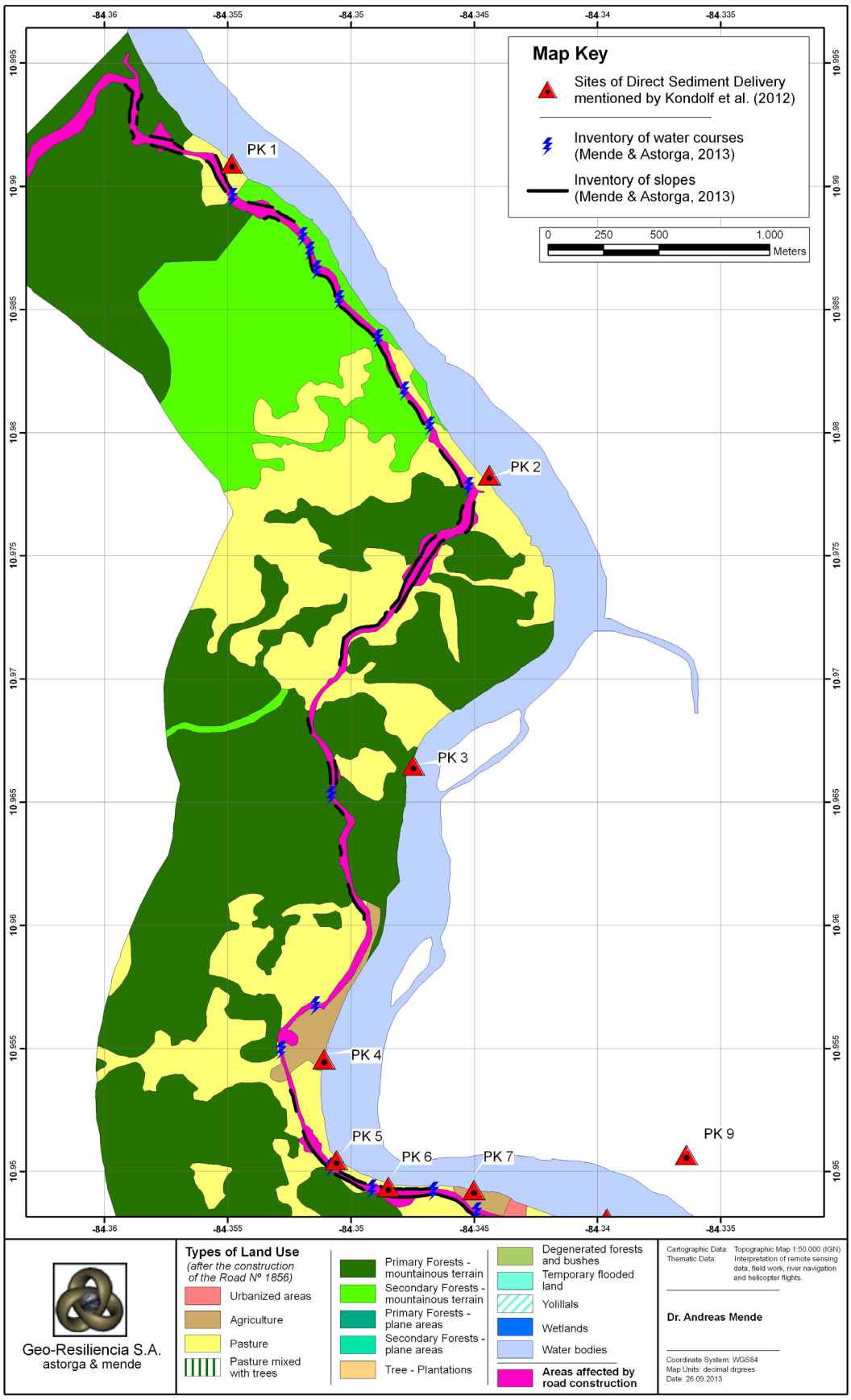
Finally a summary of the results of this report is provided including some conclusions about the importance of the 54 Kondolf sites for the San Juan River System.

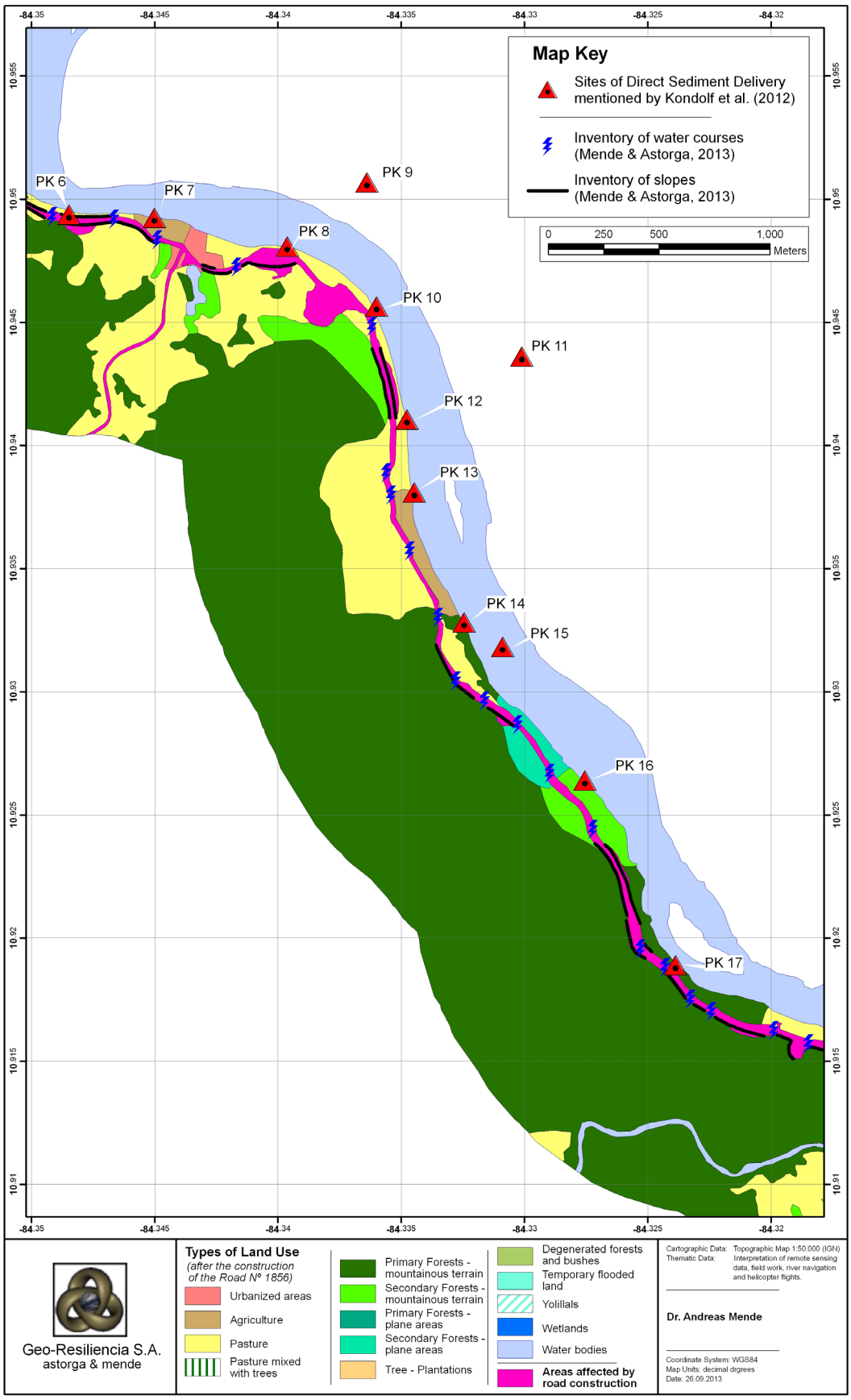
Overview map: Spatial distribution of the 54 sites specified in the Kondolf Report

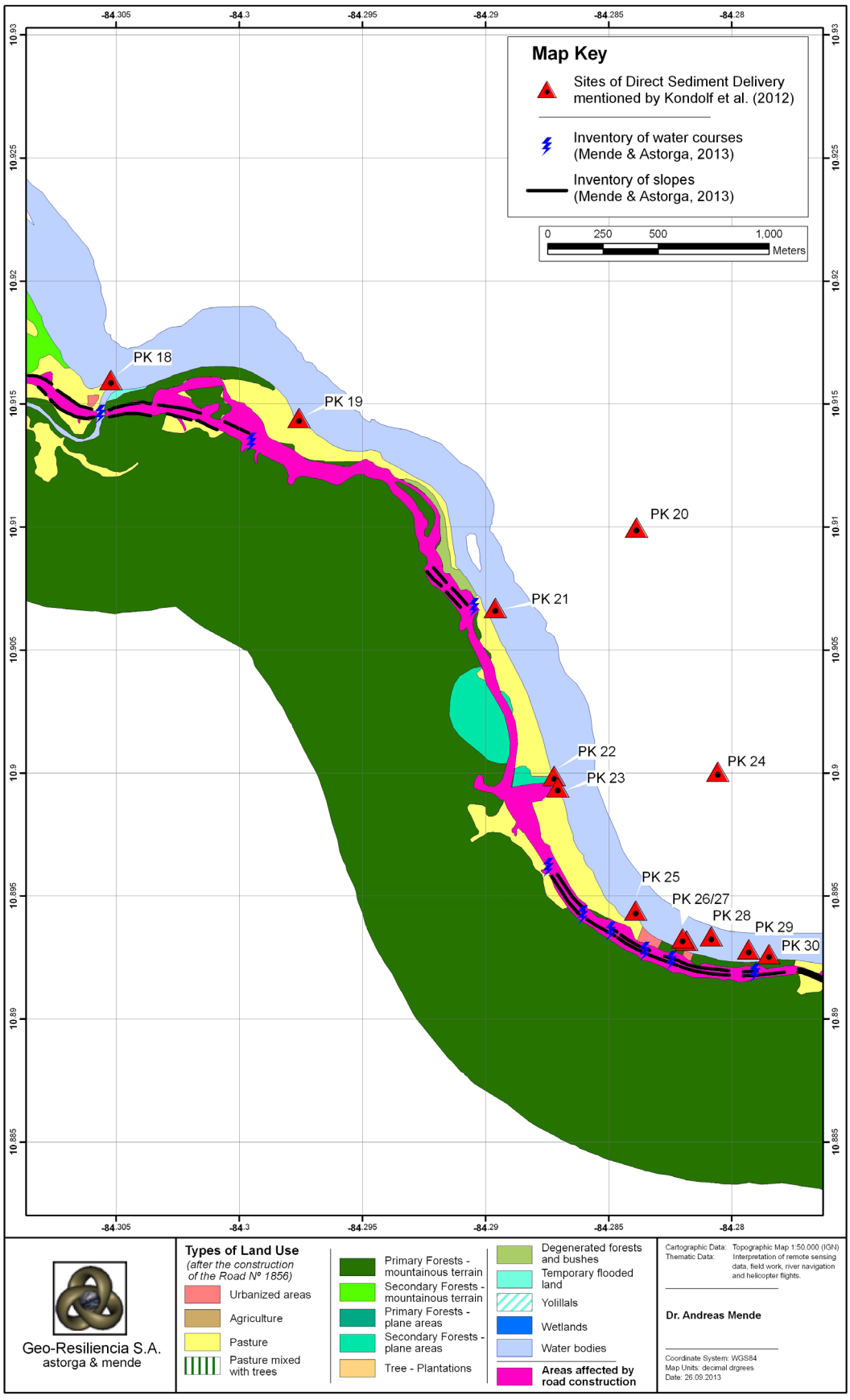

Mojón II
Rio Infiernillo
Río San Carlos
Río Sarapiquí
Delta Costa Rica
460000
470000
480000
490000
500000
510000
520000
530000
1180000
1190000
1200000
1210000
0
10,000
20,000
Meters
N
S
E
W
Map Key
Ubication of the 54 Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2013)
Border Road Nº 1856
Geo-Resiliencia S.A.
astorga, mende & asociados
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 26.09.2013

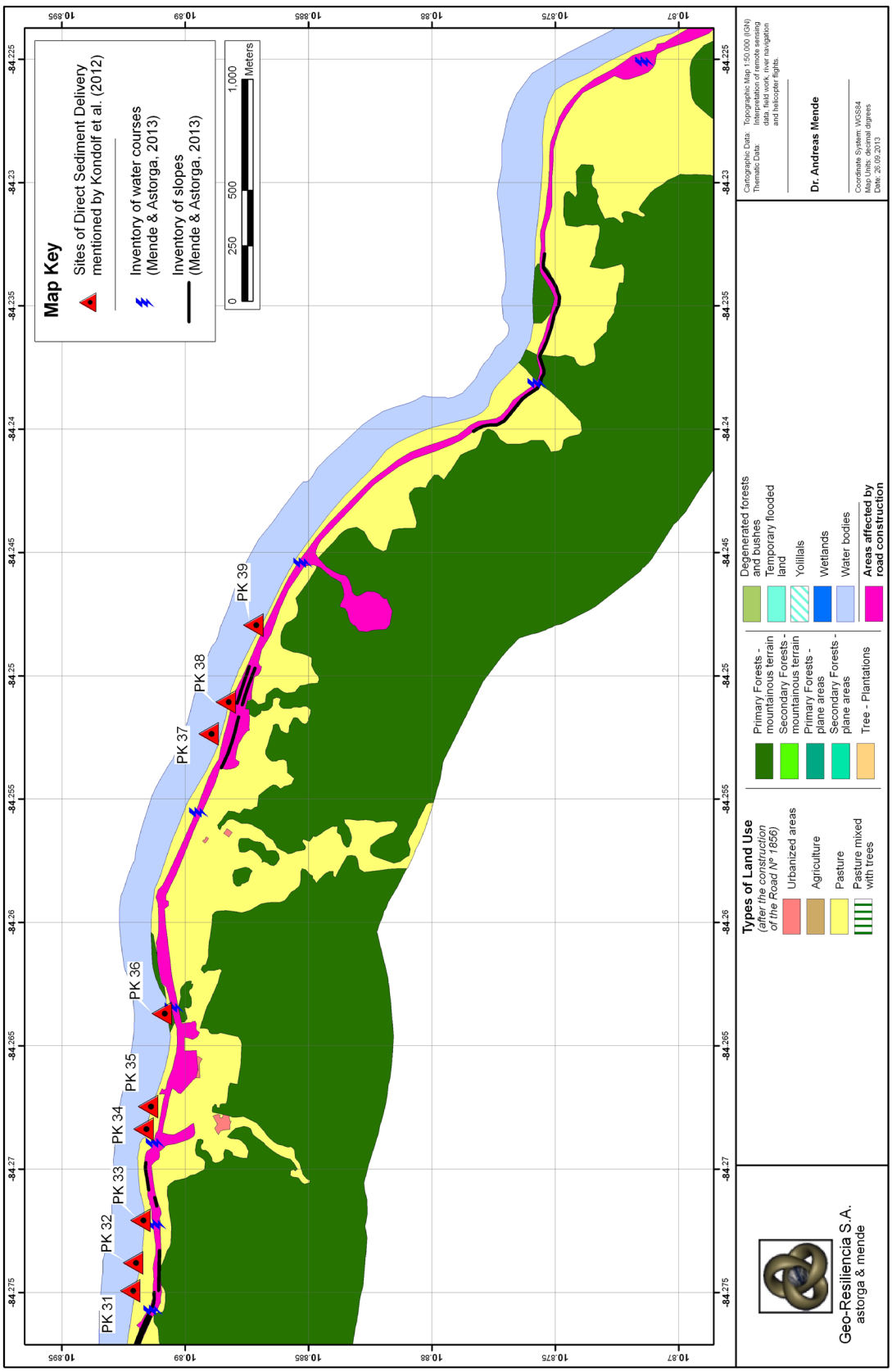
Detailed maps - Land Use, Slopes and Water Courses along the Border Road Nº 1856 in addition to the Spatial Distribution of the 54 sites specified in the Kondolf Report

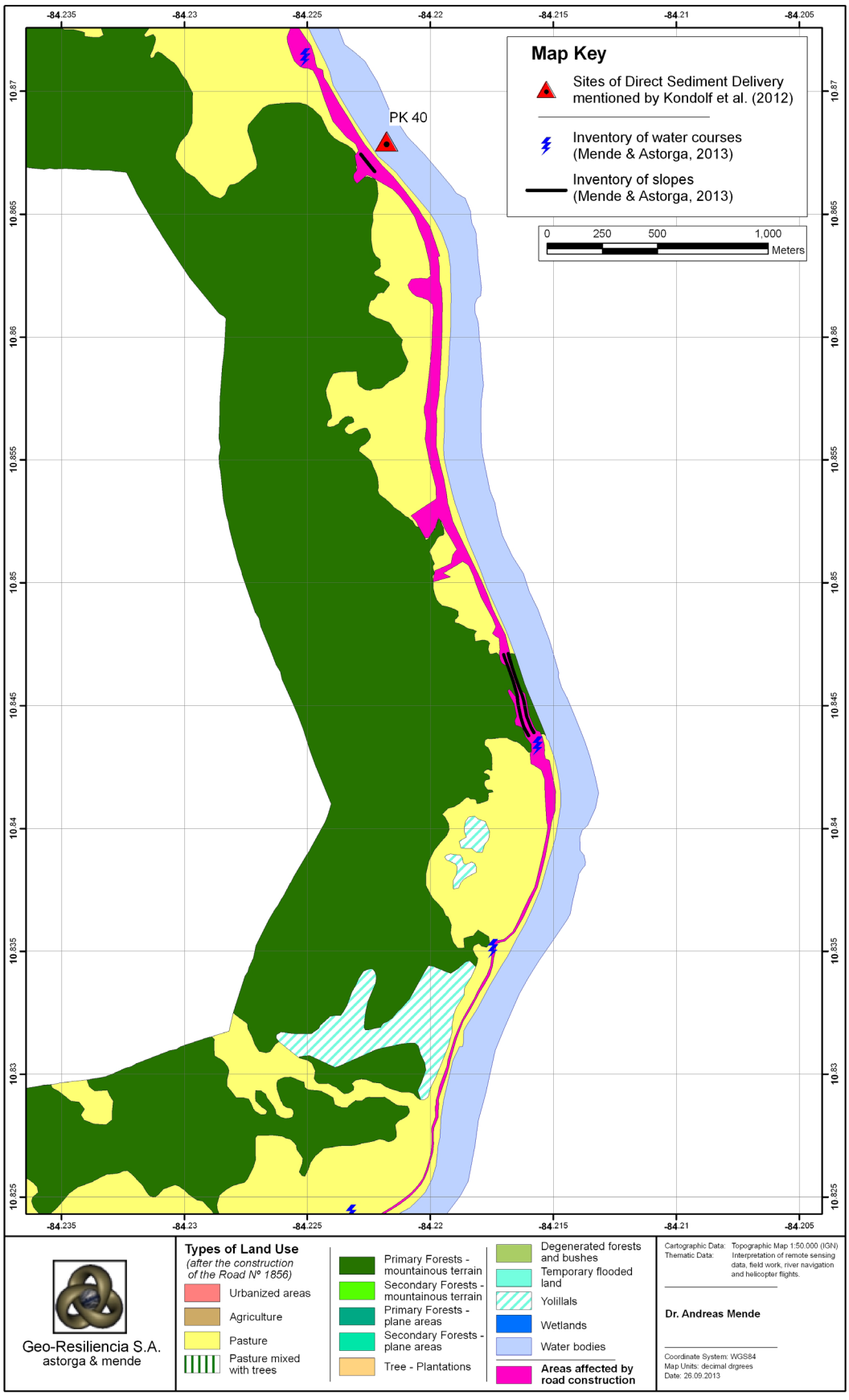
Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

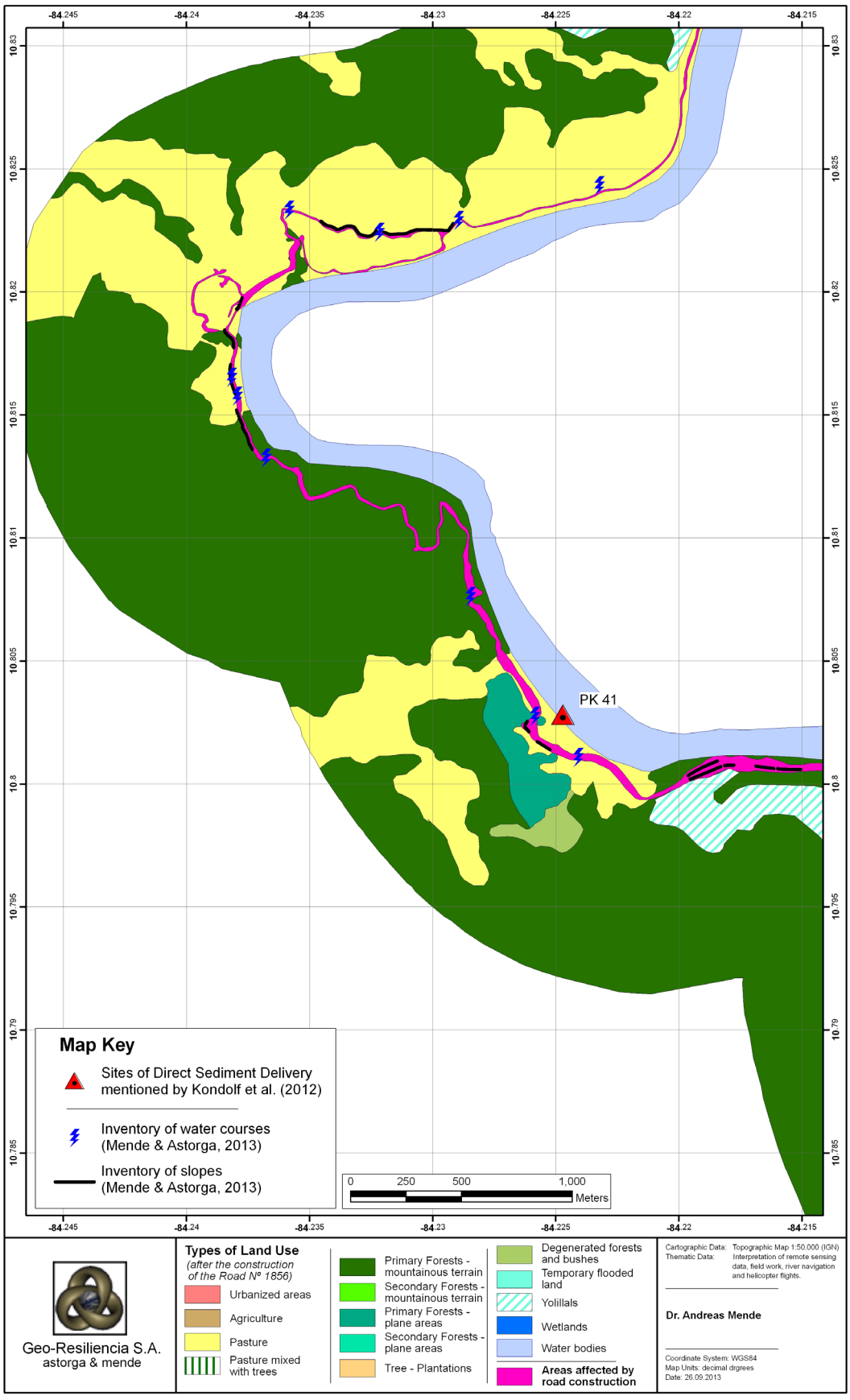

Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0 250 500 1,000 Meters
PK 1
PK 2
PK 3
PK 4
PK 5
PK 6
PK 7
PK 9
-84.36
-84.355
-84.35
-84.345
-84.34
-84.335
10.995
10.99
10.985
10.98
10.975
10.97
10.965
10.96
10.955
10.95
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 26.09.2013

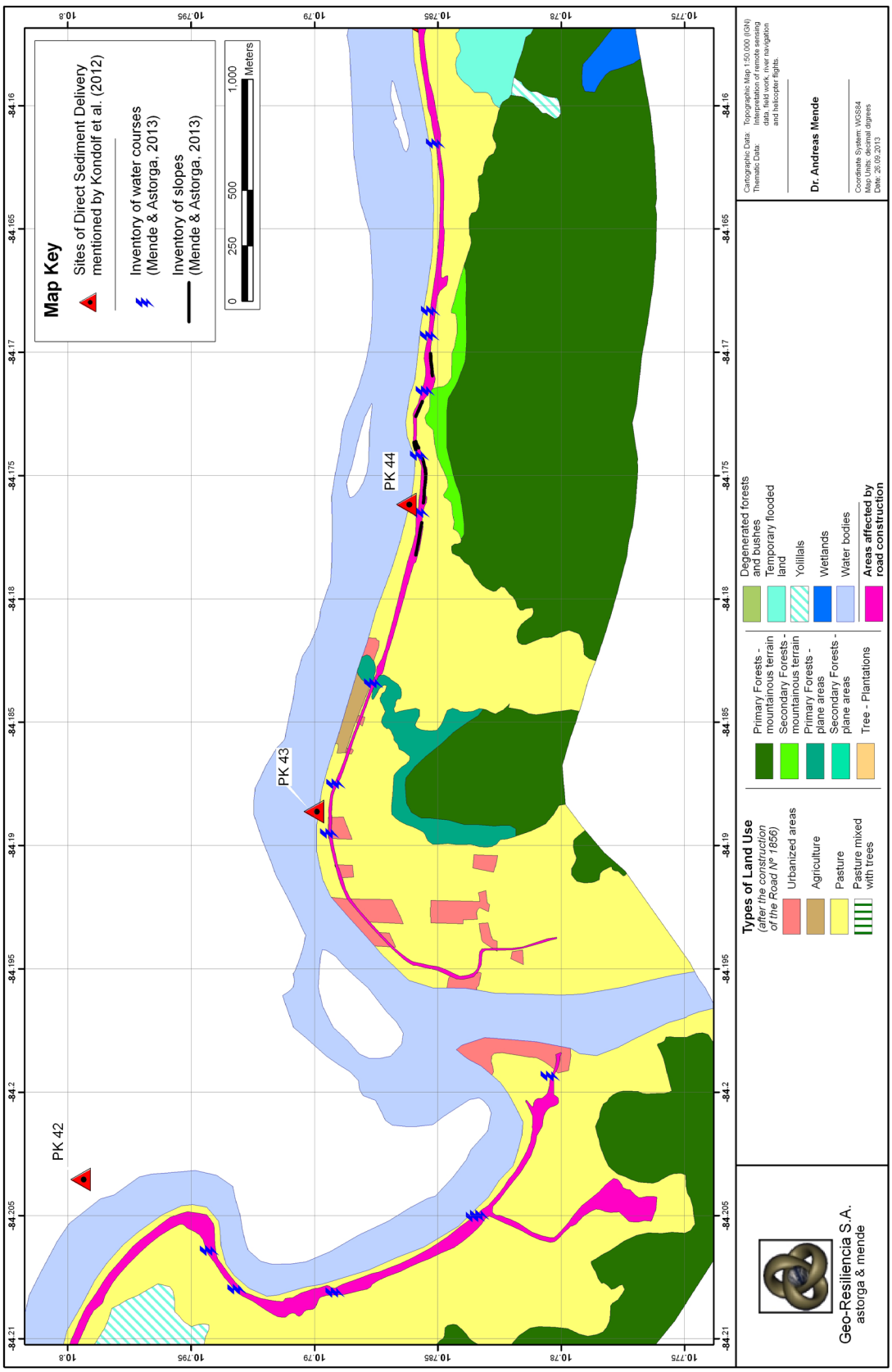

Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0 250 500 1,000 Meters
PK 6
PK 7
PK 8
PK 9
PK 10
PK 11
PK 12
PK 13
PK 14
PK 15
PK 16
PK 17
-84.35
-84.345
-84.34
-84.335
-84.33
-84.325
-84.32
10.955
10.95
10.945
10.94
10.935
10.93
10.925
10.92
10.915
10.91
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 26.09.2013

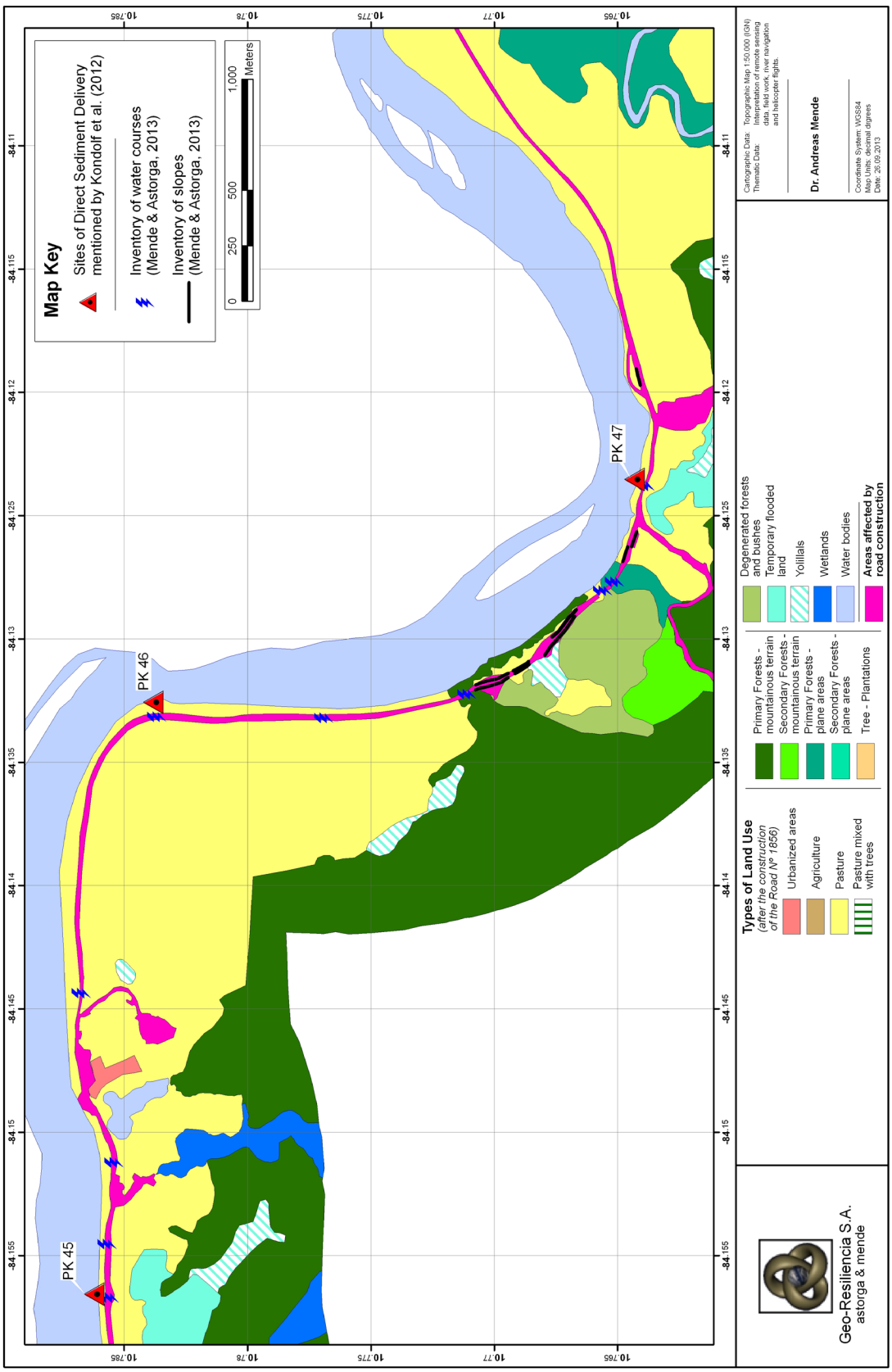

Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0 250 500 1,000 Meters
PK 18
PK 19
PK 20
PK 21
PK 22
PK 23
PK 24
PK 25
PK 26/27
PK 28
PK 29
PK 30
-84.305
-84.3
-84.295
-84.29
-84.285
-84.28
10.93
10.925
10.92
10.915
10.91
10.905
10.9
10.895
10.89
10.885
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 26.09.2013

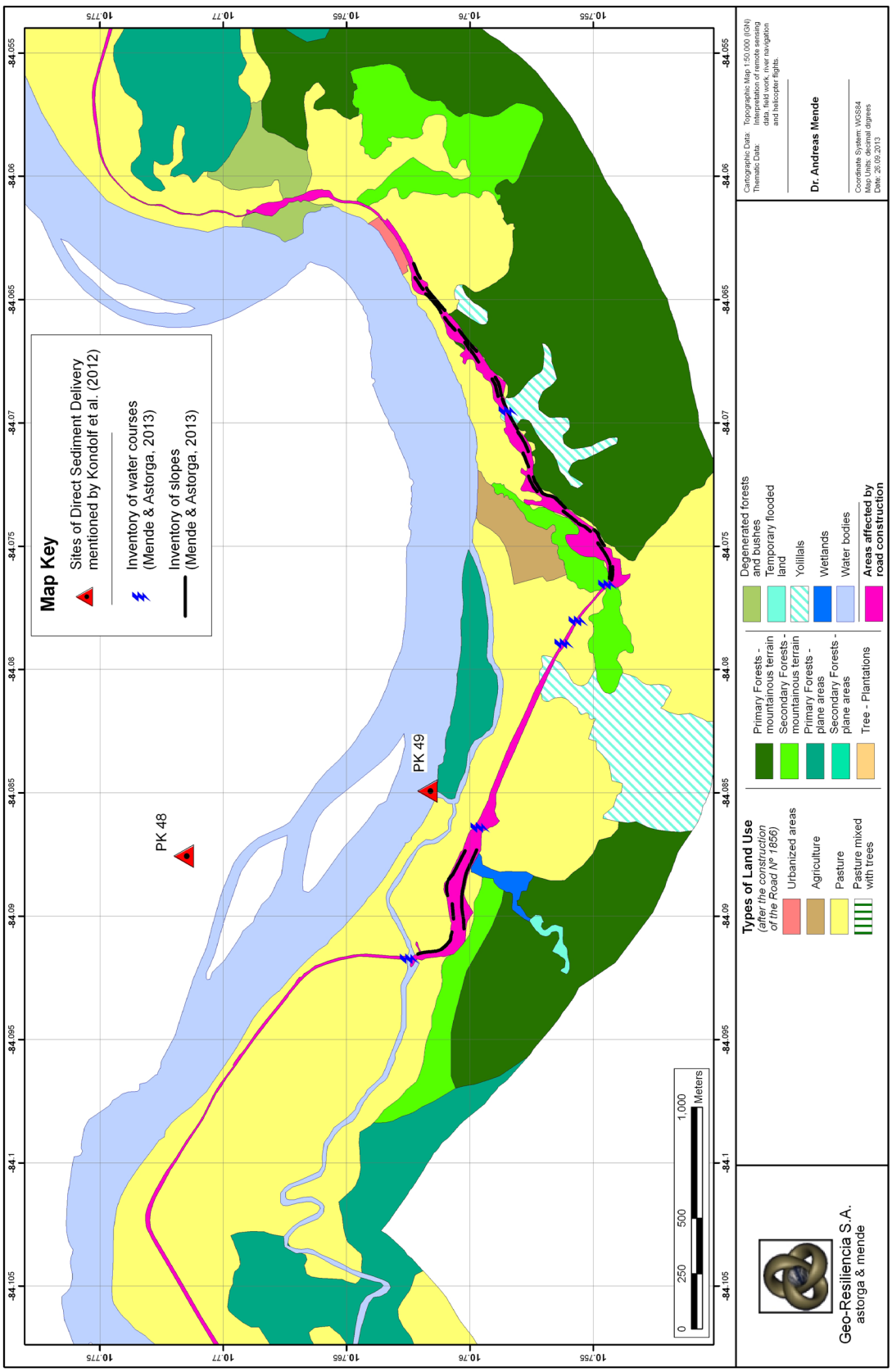

Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0
250
500
1.000
Meters
PK 31
PK 32
PK 33
PK 34
PK 35
PK 36
PK 37
PK 38
PK 39
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Units: Decimal degrees
Date: 26.09.2013
Geo-Resiliencia S.A.
astorga & mende

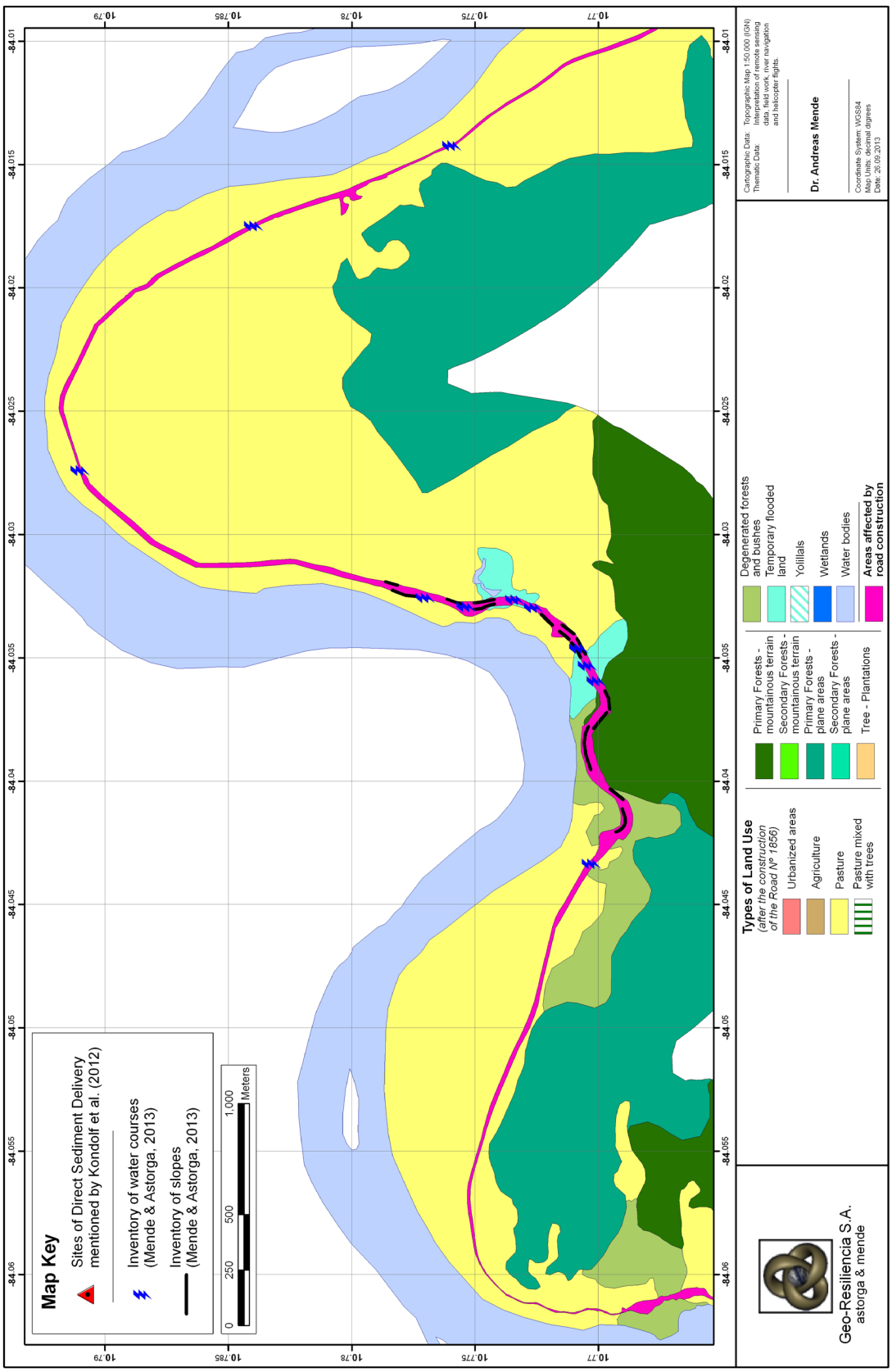

-84.235
-84.23
-84.225
-84.22
-84.215
-84.21
-84.205
10.87
10.865
10.86
10.855
10.85
10.845
10.84
10.835
10.83
10.825
Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
PK 40
0 250 500 1,000
Meters
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 26.09.2013

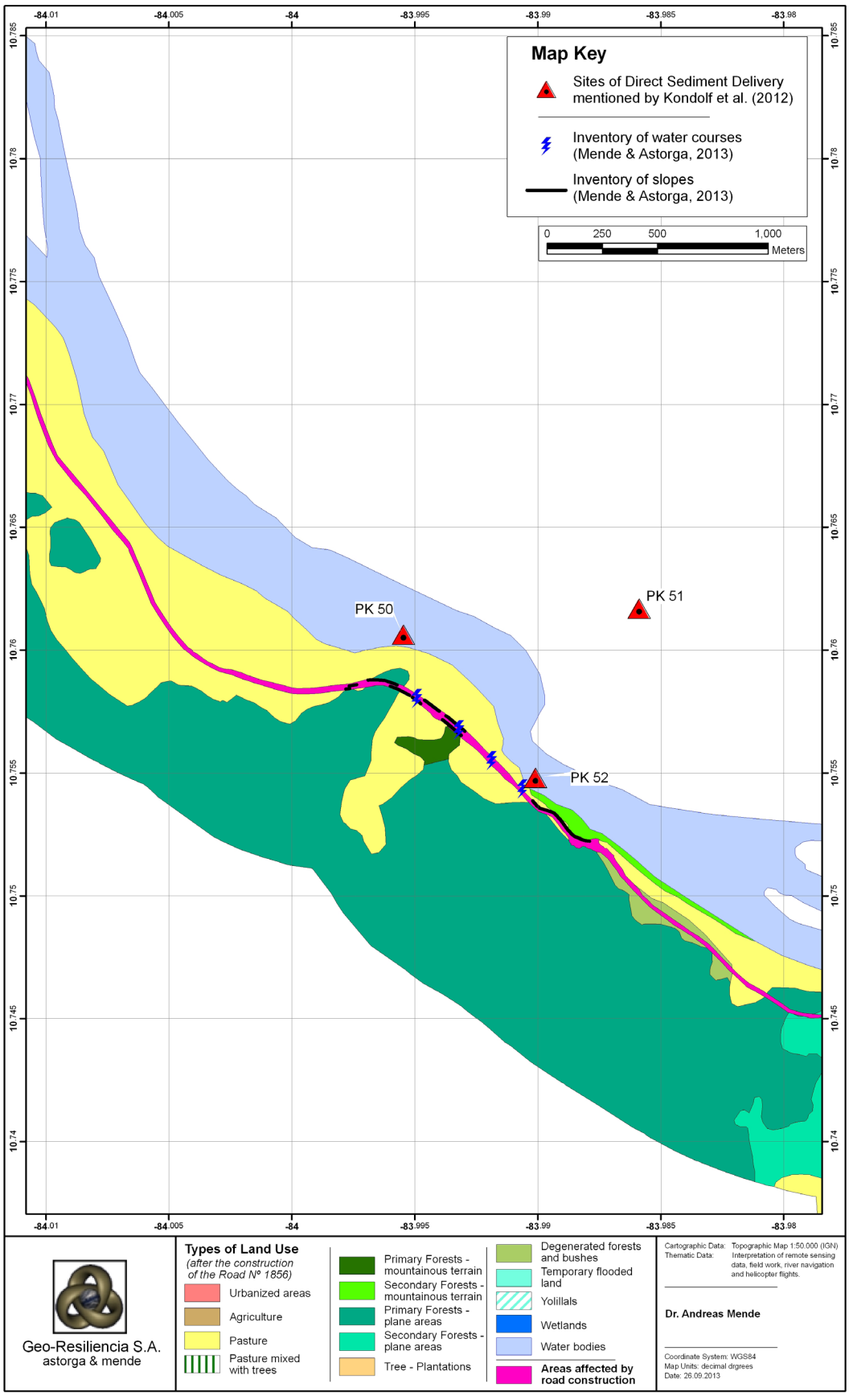

-84.245
-84.24
-84.235
-84.23
-84.225
-84.22
-84.215
10.83
10.825
10.82
10.815
10.81
10.805
10.8
10.795
10.79
10.785
PK 41
Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0 250 500 1,000
Meters
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 26.09.2013

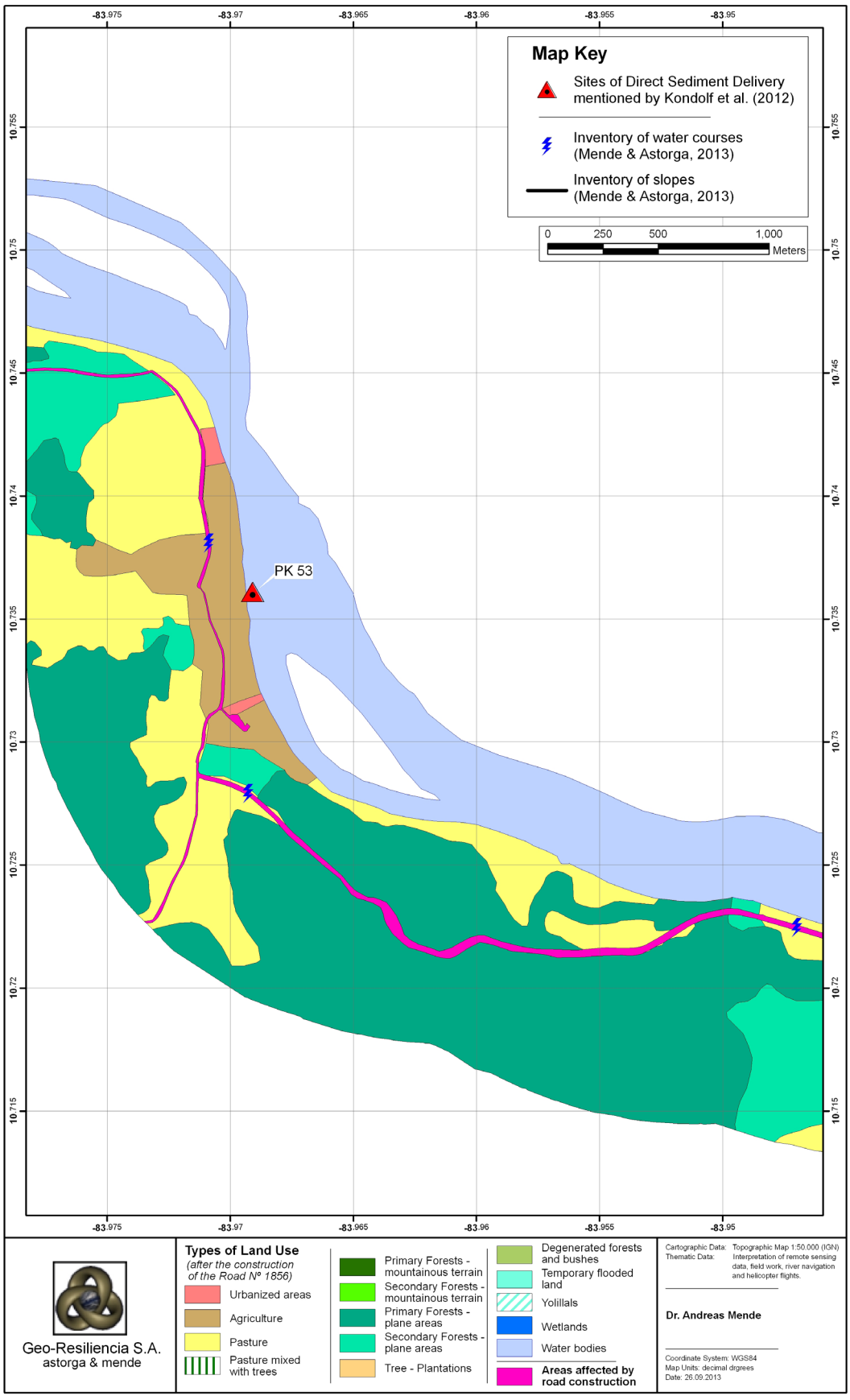

Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0
250
500
1.000
Meters
PK 42
PK 43
PK 44
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Units: Decimal degrees
Date: 26.09.2013

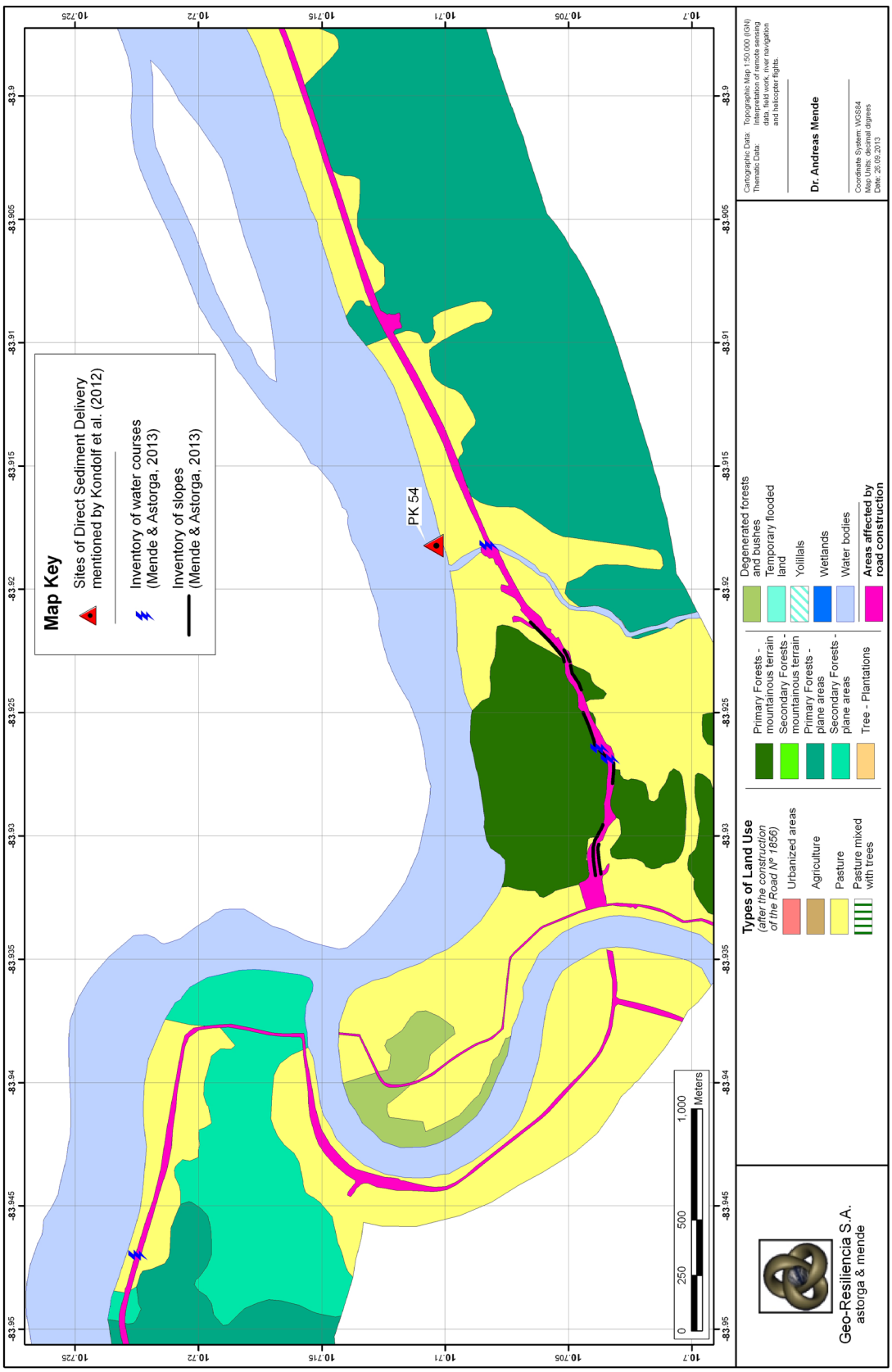

Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0
250
500
1.000
Meters
PK 45
PK 46
PK 47
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Units: Meters, decimal degrees
Date: 26.09.2013


Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
PK 48
PK 49
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
0 250 500 1,000 Meters
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Units: Decimal degrees
Date: 26.09.2013


Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0 250 500 1,000 Meters
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Units: Decimal degrees
Date: 26.09.2013
-84.06
-84.055
-84.05
-84.045
-84.04
-84.035
-84.03
-84.025
-84.02
-84.015
-84.01
10.79
10.785
10.78
10.775
10.77


Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0 250 500 1,000
Meters
PK 50
PK 51
PK 52
-84.01
-84.005
-84
-83.995
-83.99
-83.985
-83.98
10.785
10.78
10.775
10.77
10.765
10.76
10.755
10.75
10.745
10.74
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 26.09.2013


Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
0 250 500 1,000
Meters
PK 53
-83.975
-83.97
-83.965
-83.96
-83.955
-83.95
10.755
10.75
10.745
10.74
10.735
10.73
10.725
10.72
10.715
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 26.09.2013


Map Key
Sites of Direct Sediment Delivery mentioned by Kondolf et al. (2012)
Inventory of water courses (Mende & Astorga, 2013)
Inventory of slopes (Mende & Astorga, 2013)
PK 54
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
0 250 500 1,000 Meters
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 26.09.2013

Data Sheets for the 54 sites specified in the Kondolf Report

Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

***Kondolf Point:* PK 1**

X-Coordinate: - 84.35485800 **Y-Coordinate:** 10.99093000

Maximum Sediment Production at this site: **740 t/year (estimation)**

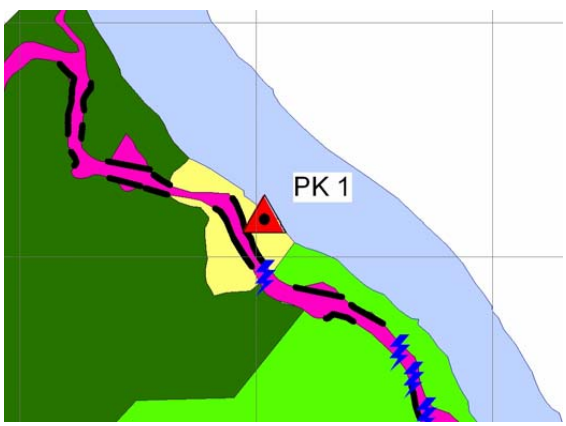
Sediment transported at this site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.022%**

Description:

Fill Slope without any drainage, water flow over the road leads to gully erosion.

Related to Slope: **T-8** ***Related to Water Cource:*** **none**



Kondolf Point: *PK 2*

X-Coordinate: -84.34441200 **Y-Coordinate:** 10.97827500

Maximum Sediment Production at this Site: **360 t/year (estimation)**

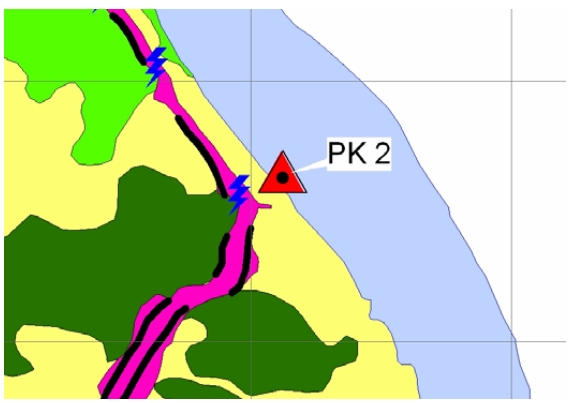
Sediment transported at this site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.011%**

Description:

A water course (C-8) has been closed by landfill, water flowing through this landfill has provoked sinking of the road structure; during heavy rain, water may flow over the road. Nevertheless only very small amounts of sediment have reached the San Juan River.

Related to Slope: **T-17** ***Related to Water Course:*** **C-8**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

Kondolf Point: PK 3

X-Coordinate: -84.34750000 **Y-Coordinate:** 10.966488

Maximum Sediment Production at this Site: **0 t/year (estimation)**

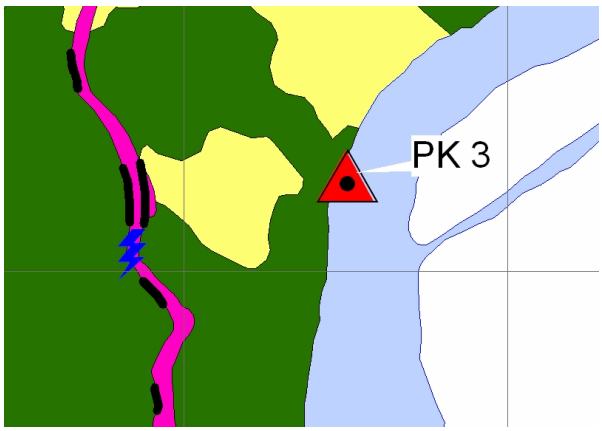
Sediment transported at this site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Probably related to the T-24 slope and/or the C-10 slope, but there is no indication that sediment from those features could reach the San Juan River, distance to the San Juan River: 350 m.

Related to Slope: **T-24 (?)** ***Related to Water Course:*** **C-10 (?)**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

***Kondolf Point:* PK 4**

X-Coordinate: -84.351123 **Y-Coordinate:** 10.954566

Maximum Sediment Production at this Site: **< 1 t/year (estimation)**

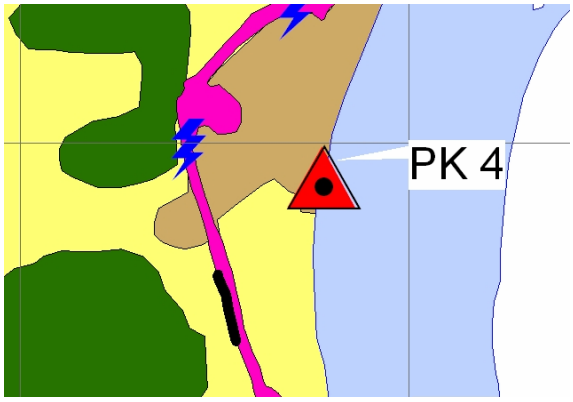
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Broken road bridge with little sediment input to the water course, by far the major part of the sediment plume reaching the San Juan River is caused by erosion within the upper watershed of the water course. This can clearly be seen in the aerial photograph in the right upper side, as this water course exhibits a heavy sediment load already upstream the road bridge and the area of open soil related to the border road.

Related to Slope: **none** ***Related to Water Course:*** **C-12**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

***Kondolf Point:* PK 5**

X-Coordinate: -84.350615 **Y-Coordinate:** 10.950459

Maximum Sediment Production at this Site: **260 t/year (estimation)**

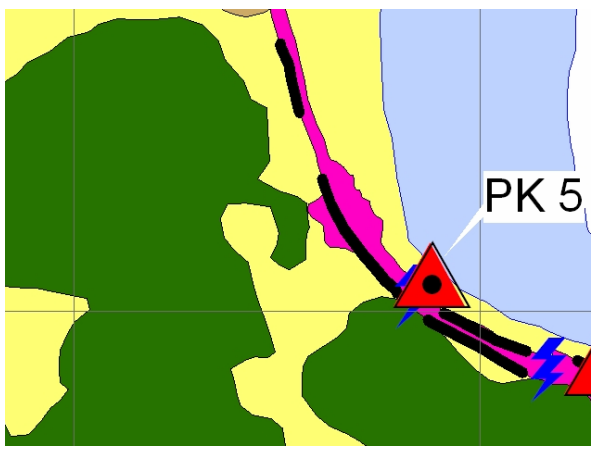
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.008%**

Description:

Drainage channel, part of the sediment eroded on the slopes within the vicinity may be transported to the San Juan River. Mitigation measures have been performed at this site.

Related to Slope: **T-29, T-30, T-31** ***Related to Water Course:*** **C-13**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

***Kondolf Point:* PK 6**

X-Coordinate: -84.348509 **Y-Coordinate:** 10.949374

Maximum Sediment Production at this Site: **1200 t/year (estimation)**

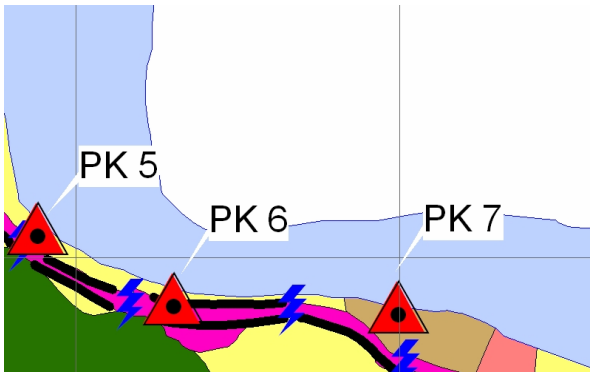
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.035%**

Description:

Drainage channel, part of the sediment eroded on the slopes within the vicinity may be transported into the San Juan River. Mitigation measures have been performed at this site.

Related to Slope: **T-30, T-31, T-32a, T-32b** ***Related to Water Course:*** **C-14**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

***Kondolf Point:* PK 7**

X-Coordinate: -84.345042 **Y-Coordinate:** 10.949253

Maximum Sediment Production at this Site: **< 1 t/year (estimation)**

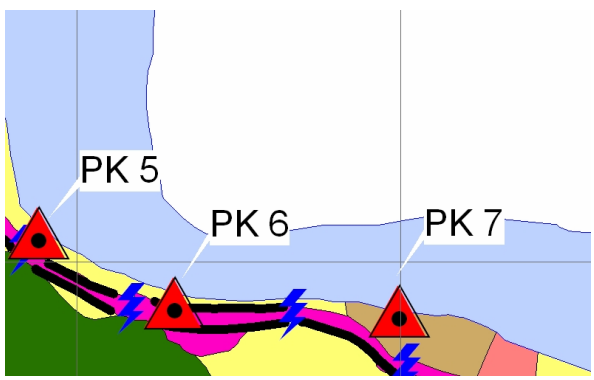
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Provisional bridge over smaller water course with slight erosion downstream of the bridge.

Related to Slope: **none** ***Related to Water Course:*** **C-16**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

***Kondolf Point:* PK 8**

X-Coordinate: -84.339647 **Y-Coordinate:** 10.948089

Maximum Sediment Production at this Site: **340 t/year (estimation)**

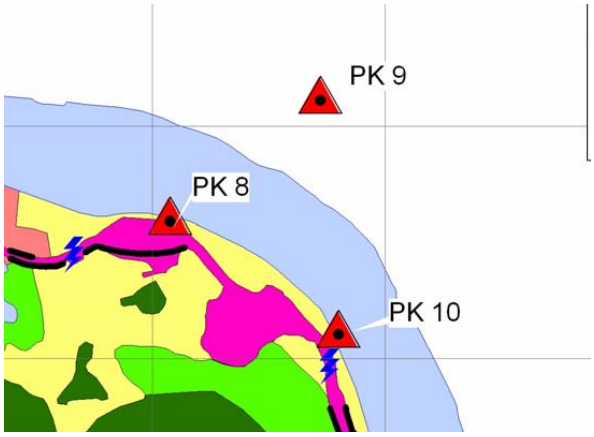
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.010%**

Description:

Slope (T-37) with mitigation measures.

Related to Slope: **T-37** ***Related to Water Course:*** **none**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

Kondolf Point: PK 9

X-Coordinate: -84.336418 **Y-Coordinate:** 10.950686

Maximum Sediment Production at this Site: **0 t/year (estimation)**

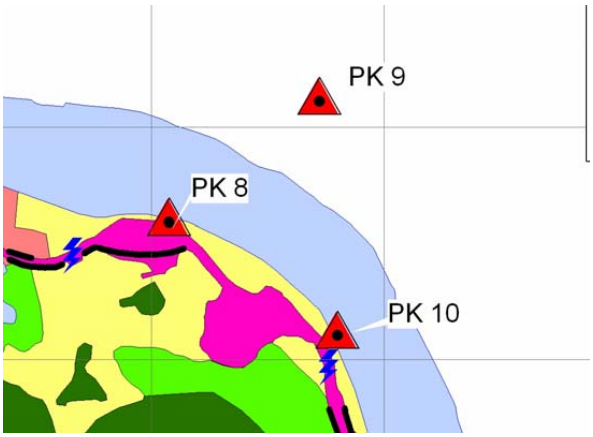
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Site located on Nicaraguan territory.

Related to Slope: **none** ***Related to Water Course:*** **none**



Kondolf Point: PK 10

X-Coordinate: -84.336028 **Y-Coordinate:** 10.945655

Maximum Sediment Production at this Site: **< *1* t/year (estimation)**

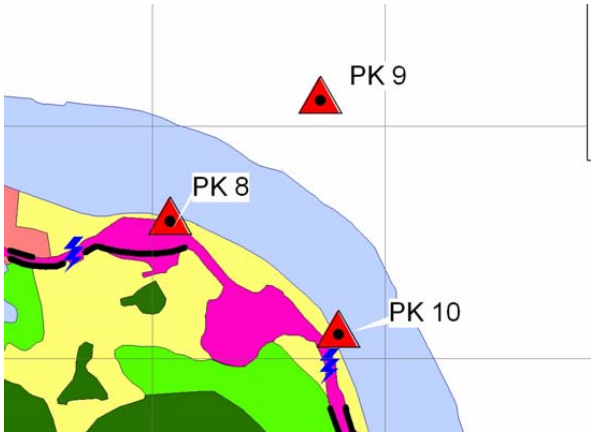
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Drainage culvert with slight erosion.

Related to Slope: **none** ***Related to Water Course:*** **C-18**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

Kondolf Point: PK 11

X-Coordinate: -84.330133 **Y-Coordinate:** 10.943617

Maximum Sediment Production at this Site: ***0*** **t/year (estimation)**

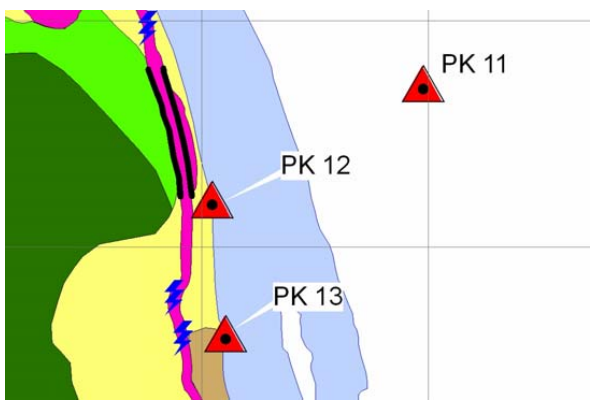
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Site located on Nicaraguan territory.

Related to Slope: none ***Related to Water Course:*** none



Kondolf Point: PK 12

X-Coordinate: -84.334792 **Y-Coordinate:** 10.941062

Maximum Sediment Production at this Site: ***4000*** **t/year (estimation)**

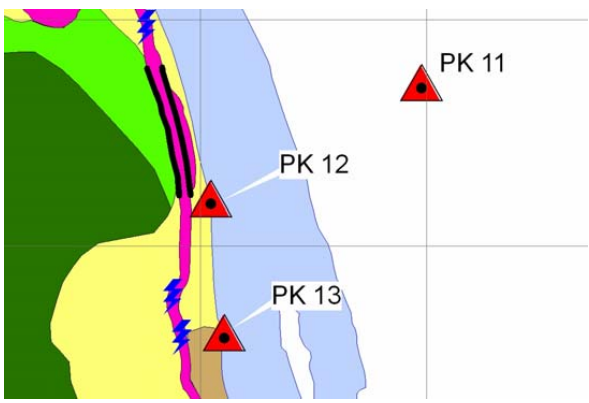
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.119%**

Description:

T-38 Slope with further mitigation measures to be carried out.

Related to Slope: **T-38** ***Related to Water Course:*** **none**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

Kondolf Point: PK 13

X-Coordinate: -84.3345 **Y-Coordinate:** 10.938104

Maximum Sediment Production at this Site: **< *1* t/year (estimation)**

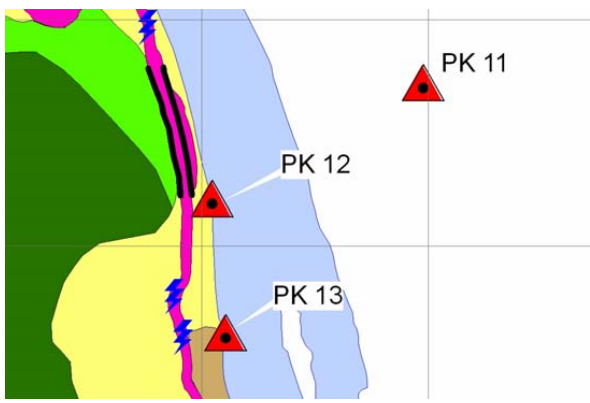
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Provisional drainage tube in an acceptable state, no indication of erosion or sedimentation to the San Juan River.

Related to Slope: **none** ***Related to Water Course:*** **C-20**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

***Kondolf Point:* PK 14**

X-Coordinate: -84.332474 **Y-Coordinate:** 10.932826

Maximum Sediment Production at this Site: **< *1* t/year (estimation)**

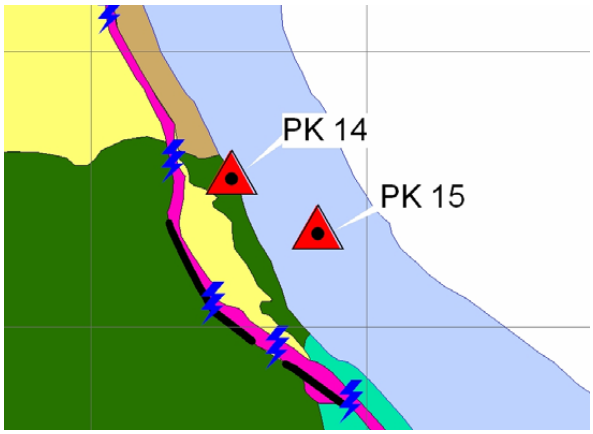
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Provisional bridge in an acceptable state, no indication of erosion or sedimentation to the San Juan River.

Related to Slope: **none** ***Related to Water Course:*** **C-22**



Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

Kondolf Point: PK 15

X-Coordinate: -84.330911 **Y-Coordinate:** 10.931832

Maximum Sediment Production at this Site: **< *1* t/year (estimation)**

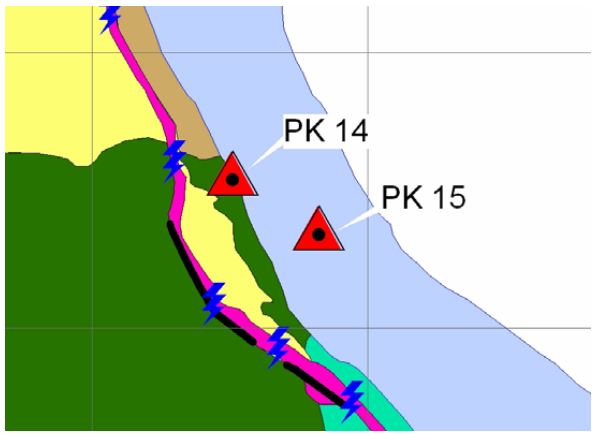
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

A water course has been closed by a landfill, water is infiltrating through this landfill but until now no severe damage can be seen; some sediment flow in direction of the San Juan River is notable, but it has not reached the river due to the plain located between the border road and the river serving as a buffer.

Related to Slope: ***Related to Water Course:*** **C-23**



Kondolf Point: *PK 16*

X-Coordinate: -84.327579 **Y-Coordinate:** 10.926409

Maximum Sediment Production at this Site: **< *1* t/year (estimation)**

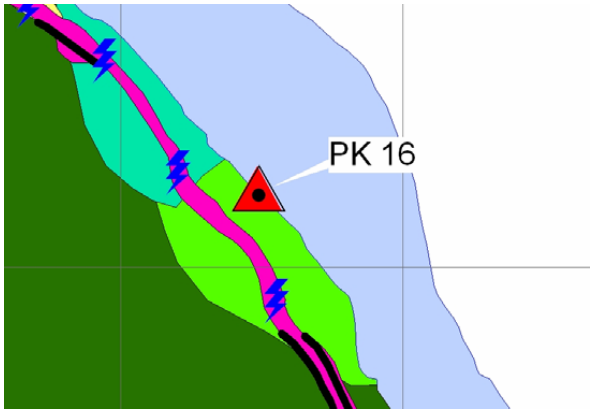
Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Exact location has no relation to any slope or water course; it could be related to the water course C-26, which is crossed by the road by means of a provisional bridge without any erosion or sedimentation towards the San Juan River.

Related to Slope: none ***Related to Water Course:*** **C-26 (?)**



Kondolf Point: PK 17

X-Coordinate: -84.323897 **Y-Coordinate:** 10.918903

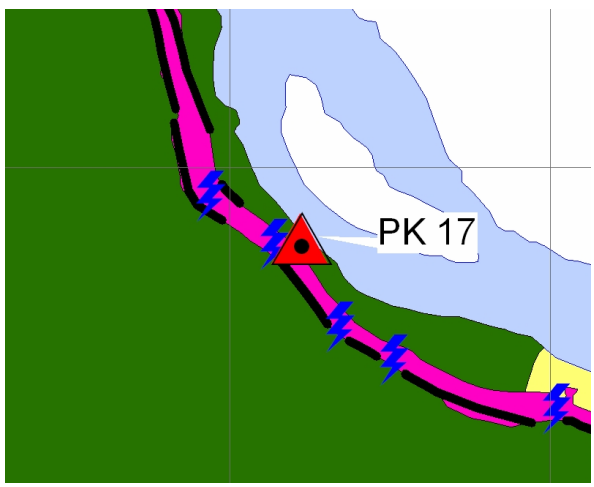
Maximum Sediment Production at this Site: ***300*** **t/year (estimation)**

Sediment transported at this Site in the San Juan River: **3,362,000 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.009%**

Description: Drainage pathway collecting the sediments from the slope T-46 with gully erosion. Mitigation works carried out.

Related to Slope: T-46 ***Related to Water Course:*** **C-29**



***Kondolf Point:* PK 18**

X-Coordinate: -84.305245 **Y-Coordinate:** 10.915977

Maximum Sediment Production at this Site: ***5580*** **t/year (estimation)**

Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

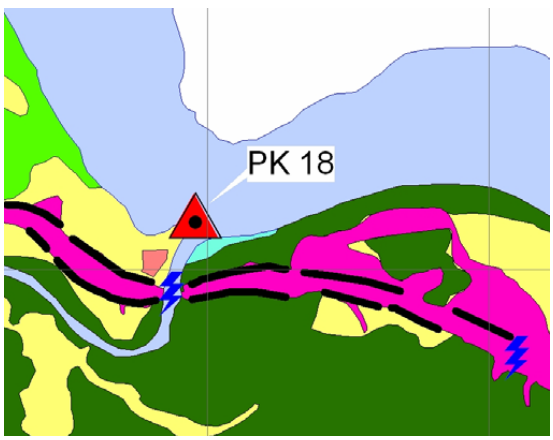
Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.157%**

Description:

Río Infiernillo water course located in the proximity of seven surrounding slopes. Nevertheless, as can be seen in the photograph, the most important part of the sediment plume reaching the San Juan River is caused by erosion within the upper watershed of the Río Infiernillo.

Related to Slope: T-56, T-57a, T-57b, T-58a, T-58b, T-59, T-60

Related to Water Course: **C-35**



Kondolf Point: PK 19

X-Coordinate: -84.297602 **Y-Coordinate:** 10.914443

Maximum Sediment Production at this Site: ***2,160*** **t/year (estimation)**

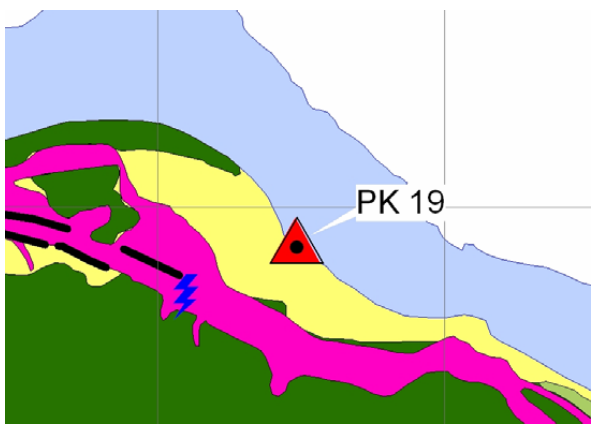
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.061%**

Description:

Wide area with open soil and high slope angles. Mitigation works carried out.

Related to Slope: T-61 ***Related to Water Course:*** **C-36**



***Kondolf Point:* PK 20**

X-Coordinate: -84.283903 **Y-Coordinate:** 10.909981

Maximum Sediment Production at this Site: ***0*** **t/year**

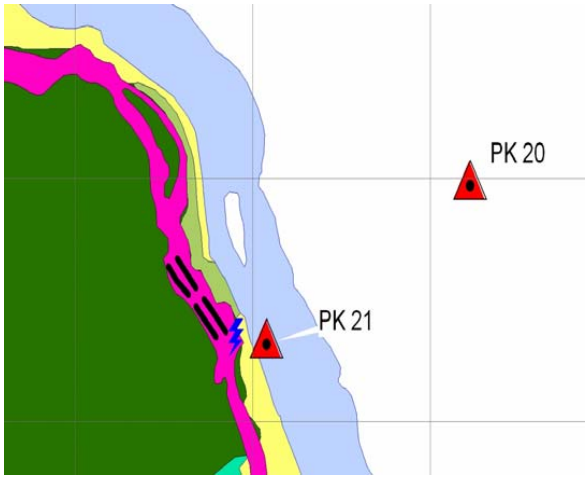
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Site located on Nicaraguan territory.

Related to Slope: none ***Related to Water Course:*** **none**



Kondolf Point: PK 21

X-Coordinate: -84.289629 **Y-Coordinate:** 10.90672

Maximum Sediment Production at this Site: ***2,070*** **t/year (estimation)**

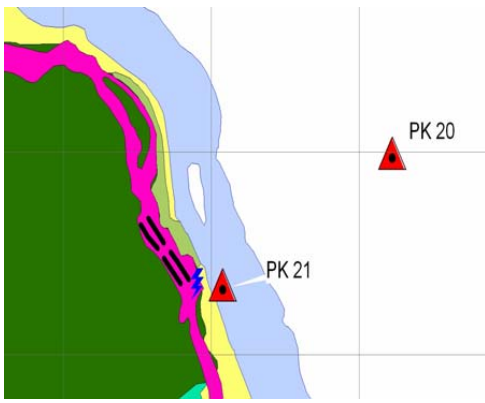
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.058%**

Description:

Location characterized by deep gully erosion and landslides.

Related to Slope: T-65 ***Related to Water Course:*** **C-37**



Kondolf Point: PK 22 and PK 23

X-Coordinate (PK 22): -84.28725 **Y-Coordinate (PK 22):** 10.899889

X-Coordinate (PK 23): -84.287094 **Y-Coordinate (PK 23):** 10.899421

Maximum Sediment Production at this Site: **< *1* t/year (rough estimation)**

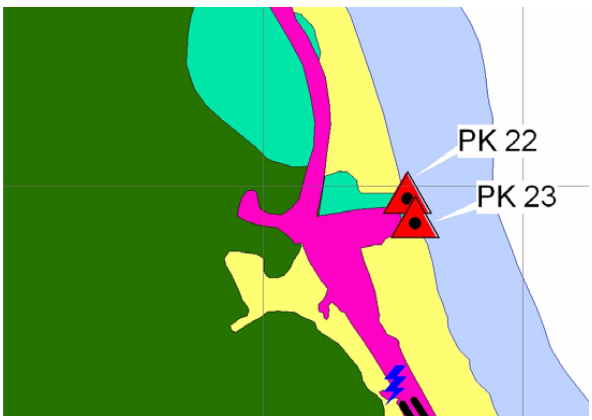
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

For the points PK 21 and PK 22 up to now there could not be collected any field data so fare, because during field work very bad weather conditions did not permit any data collection at this site. Based on satellite images sediment input to the San Juan River cannot be proven. As PK 21 and PK 22 are located very close to each other they may refer to the same site.

Related to Slope: none ***Related to Water Course:*** none



Kondolf Point: PK 24

X-Coordinate: -84.280593 **Y-Coordinate:** 10.90006

Maximum Sediment Production at this Site: ***0*** **t/year**

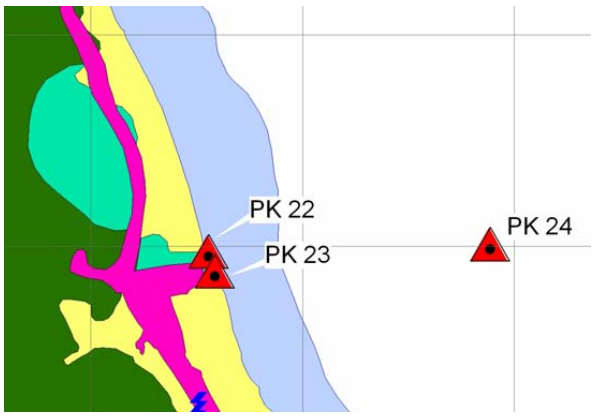
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Site located on Nicaraguan territory.

Related to Slope: none ***Related to Water Course:*** **none**



Kondolf Point: *PK 25*

X-Coordinate: -84.283927 **Y-Coordinate:** 10.89442

Maximum Sediment Production at this Site: ***2,250*** **t/year (estimation)**

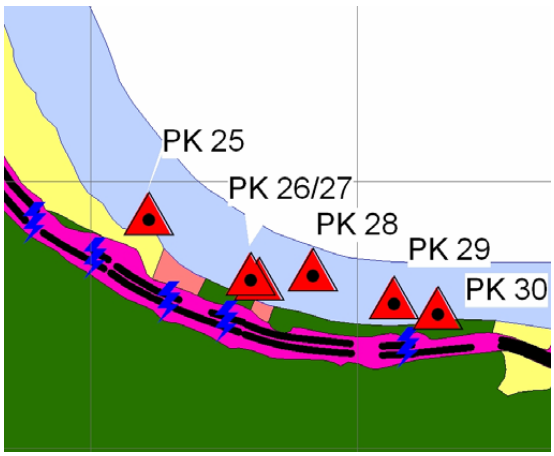
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.063%**

Description:

Fill slope with gully erosion and landslides.

Related to Slope: T-68



Related to Water Course: **C-40**

Kondolf Point: *PK 26 and PK 27*

X-Coordinate (PK 26): -84.281868 **Y-Coordinate (PK 26):** 10.893188

X-Coordinate (PK 27): -84.282023 **Y-Coordinate (PK 27):** 10.893287

Maximum Sediment Production at this Site: ***4,500*** **t/year (estimation)**

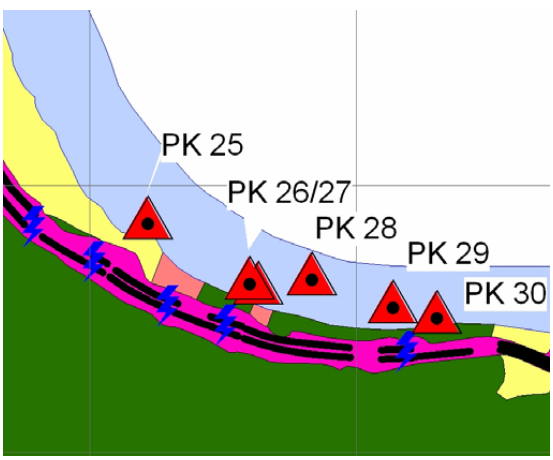
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.126%**

Description:

Location PK 26 y PK 27 probably refer to the same site, characterized as a fill slope with gully erosion and landslides.

Related to Slope: T-72



Related to Water Course: **C-42**

***Kondolf Point:* PK 28**

X-Coordinate: -84.280862 **Y-Coordinate:** 10.89337

Maximum Sediment Production at this Site: ***3,400*** **t/year (estimation)**

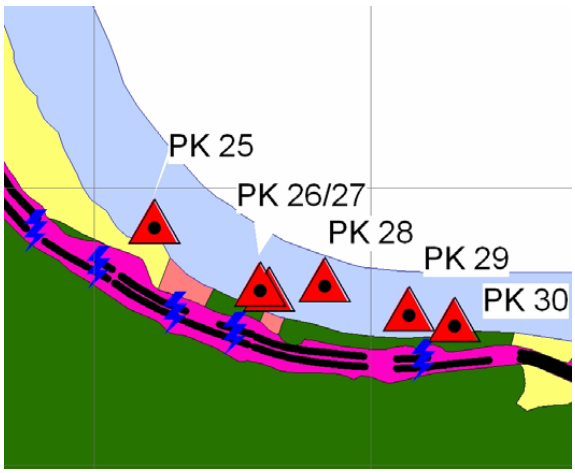
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.095%**

Description:

Related to the cut slope T-73 characterized by deep gully erosion and landslides.

Related to Slope: T-73 ***Related to Water Course:*** **none**



Kondolf Point: PK 29

X-Coordinate: -84.279346 **Y-Coordinate:** 10.892837

Maximum Sediment Production at this Site: ***5,000*** **t/year (estimation)**

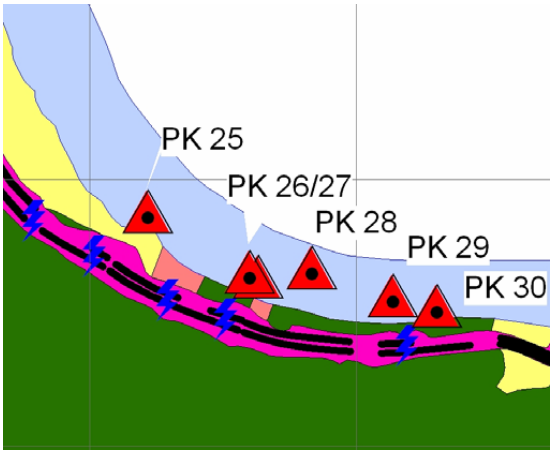
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.141%**

Description:

Location related to fill slope T-74 passing by a little valley with a water course (C-43).

Related to Slope: T-74



Related to Water Course: **C-43**

Kondolf Point: *PK 30*

X-Coordinate: -84.278523 **Y-Coordinate:** 10.892642

Maximum Sediment Production at this Site: ***< 1 t/year (estimation)***

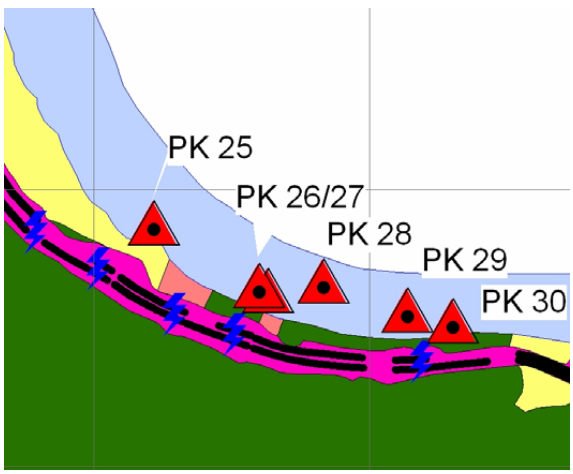
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Related to the cut slope T-75, at present there is not visible any sediment flow in direction of the San Juan River.

Related to Slope: T-75 ***Related to Water Course:*** **none**



Kondolf Point: PK 31

X-Coordinate: -84.274959 **Y-Coordinate:** 10.89224

Maximum Sediment Production at this Site: ***50*** **t/year (estimation)**

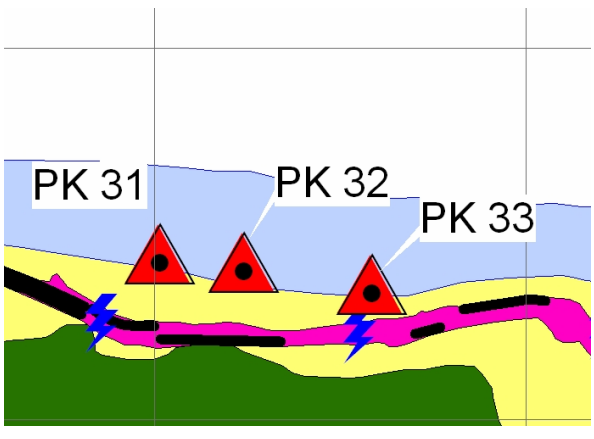
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.001%**

Description:

Related to fill slope T-77 and water course C-44b. Slight sediment flow towards the San Juan River.

Related to Slope: **T-77** ***Related to Water Course:*** **C-44b**



Kondolf Point: *PK 32*

X-Coordinate: -84.273831 Y-Coordinate: 10.892122

Maximum Sediment Production at this Site: **< *1* t/year (estimation)**

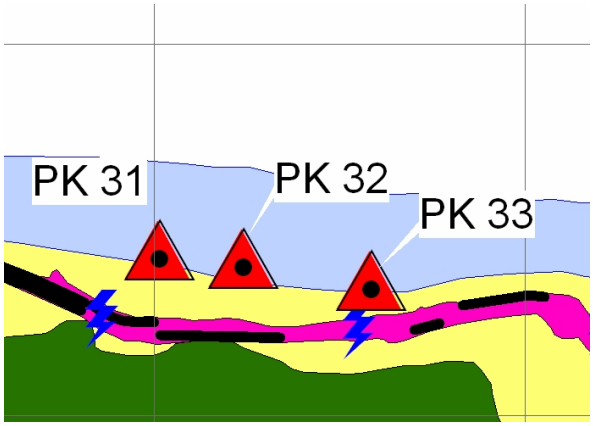
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Related to cut slope T-78, there is no sign for any sediment flow in direction of the San Juan River.

Related to Slope: **T-78** ***Related to Water Course:*** **none**



Kondolf Point: PK 33

X-Coordinate: -84.272108 **Y-Coordinate:** 10.891831

Maximum Sediment Production at this Site: ***90*** **t/year (estimation)**

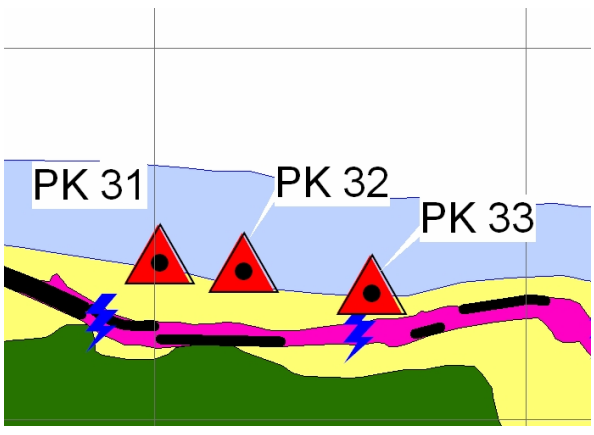
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.002%**

Description:

Related to water course C-44 and T-79 and T-80 slopes, slight sediment flow.

Related to Slope: **T-79, T-80** ***Related to Water Course:*** **C-44**



***Kondolf Point:* PK 34**

X-Coordinate: -84.268405 **Y-Coordinate:** 10.891704

Maximum Sediment Production at this Site: **< *1* t/year (estimation)**

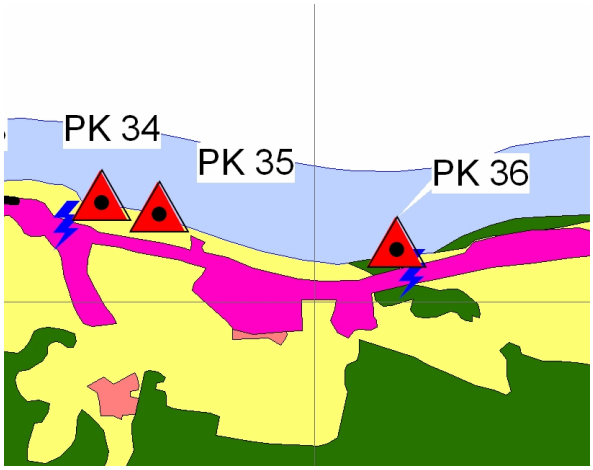
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Small river (C-45) without any bridge, there is no sign for any sediment flow in direction of the San Juan River

Related to Slope: **none** ***Related to Water Course:*** **C-45**



Kondolf Point: PK 35

X-Coordinate: -84.267486 **Y-Coordinate:** 10.891516

Maximum Sediment Production at this Site: **< *1* t/year (estimation)**

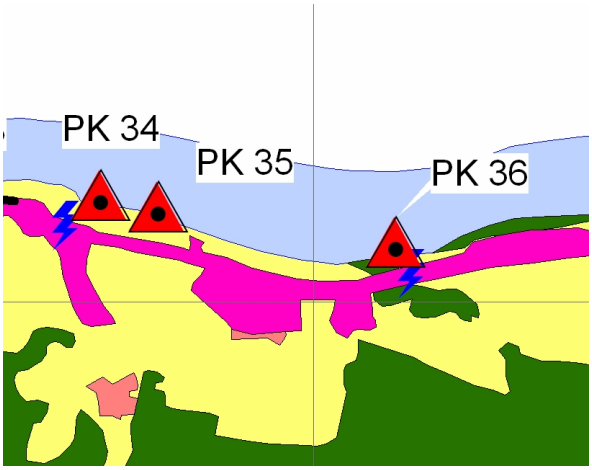
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

There is not visible any source of sediment at this site.

Related to Slope: **none** ***Related to Water Course:*** none



***Kondolf Point:* PK 36**

X-Coordinate: -84.263719 **Y-Coordinate:** 10.890958

***Maximum Sediment Production at this Site:* erosive water cause, estimation not possible at this moment**

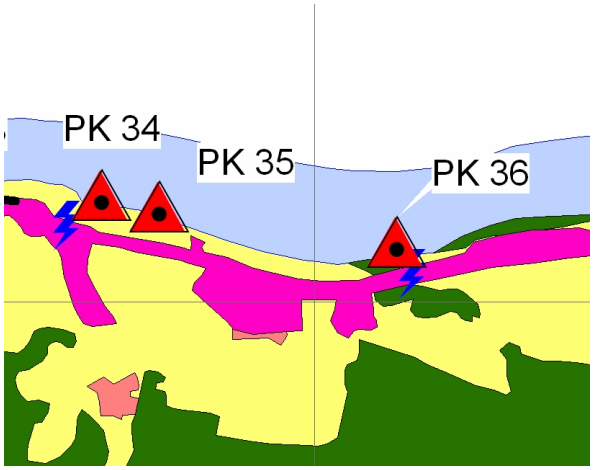
***Sediment transported at this Site in the San Juan River:* 3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **No data**

Description:

At this site the road is interrupted for the reason of the destruction of larger drainage tube.

Related to Slope: **none** ***Related to Water Course:*** **C-46**



Kondolf Point: PK 37

X-Coordinate: -84.252381 **Y-Coordinate:** 10.889064

Maximum Sediment Production at this Site: ***890 t/year (estimation)***

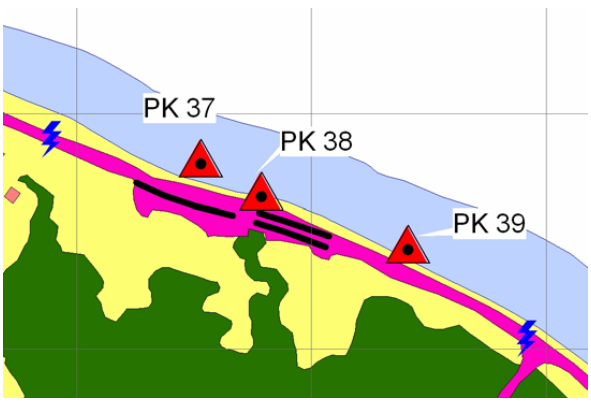
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.025%**

Description:

Cut slope T-81 with gully erosion.

Related to Slope: **T-81** ***Related to Water Course:*** **none**



***Kondolf Point:* PK 38**

X-Coordinate: -84.251092 **Y-Coordinate:** 10.888361

***Maximum Sediment Production at this Site:* 390 t/year (estimation)**

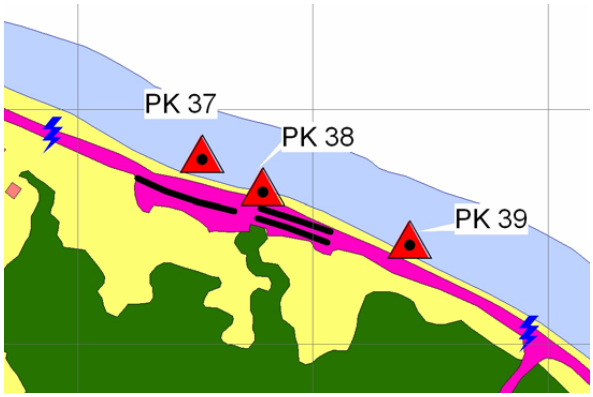
***Sediment transported at this Site in the San Juan River:* 3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.011%**

Description:

Cut slope with gully erosion.

Related to Slope: **T-82** ***Related to Water Course:*** **none**



Kondolf Point: PK 39

X-Coordinate: -84.247971 **Y-Coordinate:** 10.887251

Maximum Sediment Production at this Site: ***< 1 t/year (estimation)***

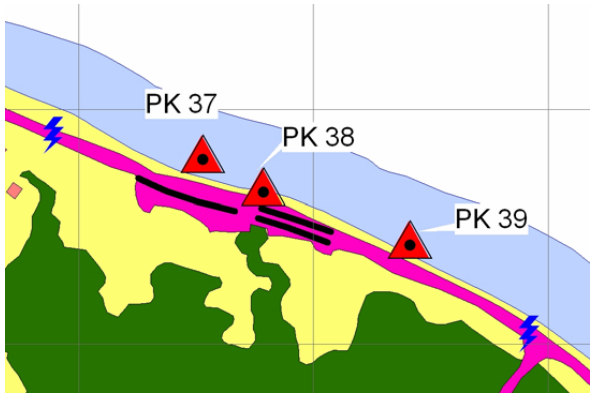
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

There is not visible any source of sediment at this site.

Related to Slope: **none** ***Related to Water Course:*** **none**



Kondolf Point: PK 40

X-Coordinate: -84.221807 **Y-Coordinate:** 10.867978

Maximum Sediment Production at this Site: ***< 1 t/year (estimation)***

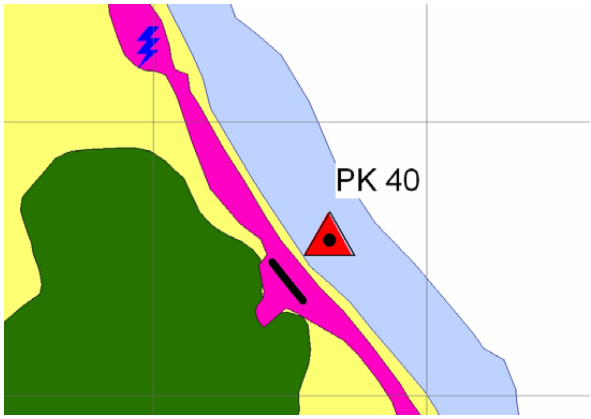
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Sediment flow is predominantly related to a farm house and its animals, and has no relation to the border road.

Related to Slope: **T-84** ***Related to Water Course:*** **none**



Kondolf Point: PK 41

X-Coordinate: -84.224737 **Y-Coordinate:** 10.802815

Maximum Sediment Production at this Site: ***30 t/year (estimation)***

Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

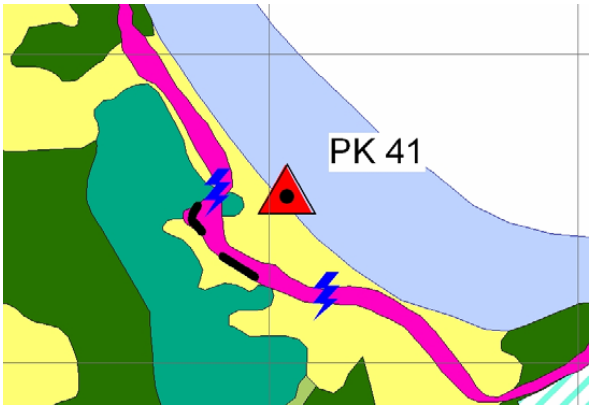
Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.001%**

Description:

Sediment production is caused by erosion within the upper watershed of the water course, with minimal input of erosion products coming from slopes related to the border road.

Related to Slope: **T-92, T-93**

Related to Water Course: **C-61**



Kondolf Point: PK 42

X-Coordinate: -84.203566 **Y-Coordinate:** 10.799494

Maximum Sediment Production at this Site: ***0 t/year***

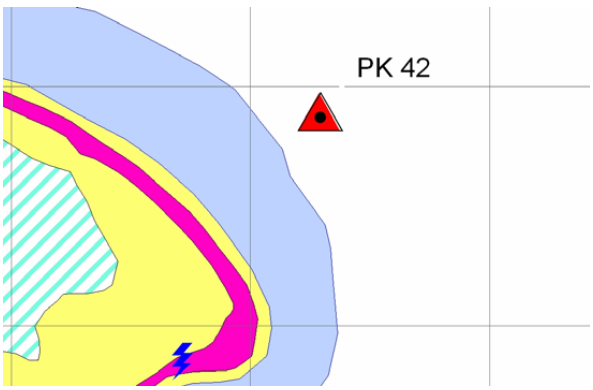
Sediment transported at this Site in the San Juan River: **3,559,500 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Site located on Nicaraguan territory.

Related to Slope: **none** ***Related to Water Course:*** **none**



Kondolf Point: PK 43

X-Coordinate: -84.188654 **Y-Coordinate:** 10.790028

Maximum Sediment Production at this Site: ***< 1 t/year (estimation)***

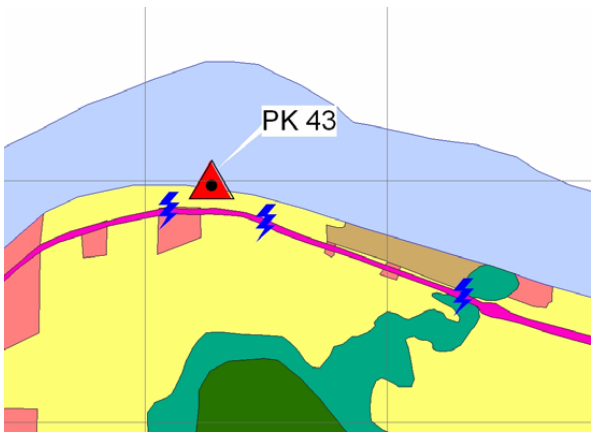
Sediment transported at this Site in the San Juan River: **7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Provisional drainage tube, acceptable present state, no indication of erosion or sedimentation to the San Juan River.

Related to Slope: **none** ***Related to Water Course:*** **C-67**



Kondolf Point: ***PK 44***

X-Coordinate: -84.176205 **Y-Coordinate:** 10.786282

Maximum Sediment Production at this Site: ***< 1 t/year (estimation)***

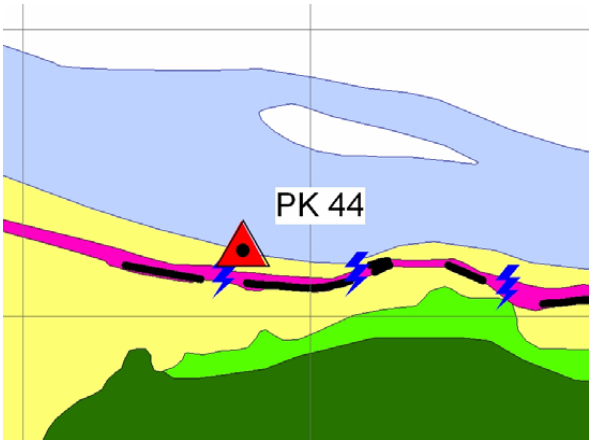
Sediment transported at this Site in the San Juan River: **7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Drainage tube in an acceptable state no indication of erosion or sedimentation to the San Juan River.

Related to Slope: **none** ***Related to Water Course:*** **C-70**



Kondolf Point: PK 45

X-Coordinate: -84.156595 **Y-Coordinate:** 10.786223

Maximum Sediment Production at this Site: ***< 1 t/year (estimation)***

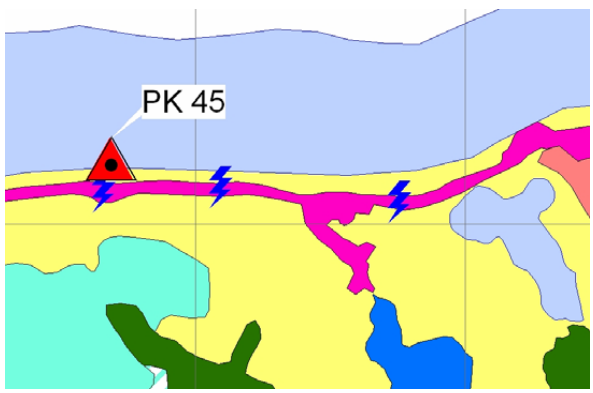
Sediment transported at this Site in the San Juan River: **7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Provisional drainage tube, acceptable present state, no indication of erosion or sedimentation to the San Juan River.

Related to Slope: **none** ***Related to Water Course:*** **C-76**



***Kondolf Point:* PK 46**

X-Coordinate: -84.132591 **Y-Coordinate:** 10.783828

***Maximum Sediment Production at this Site:* < 1 t/year (estimation)**

***Sediment transported at this Site in the San Juan River:* 7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Drainage tube with slight erosion downstream the road.

Related to Slope: **none** ***Related to Water Course:*** **C-80**

Kondolf Point: PK 47

X-Coordinate: -84.123554 **Y-Coordinate:** 10.764318

Maximum Sediment Production at this Site: **< 1 t/year (estimation)**

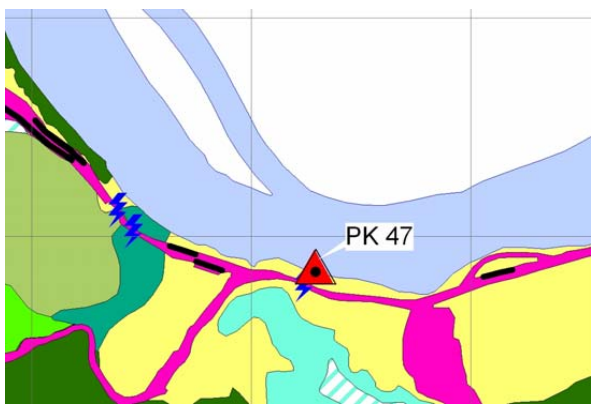
Sediment transported at this Site in the San Juan River: **7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Provisional drainage tube, acceptable present state, no indication of erosion or sedimentation to the San Juan River related to the road. Slight sediment input to the San Juan River is caused by a settlement at the edge of the river.

Related to Slope: **none** ***Related to Water Course:*** **C-85**



Kondolf Point: PK 48

X-Coordinate: -84.087589 **Y-Coordinate:** 10.771606

Maximum Sediment Production at this Site: ***0 t/year***

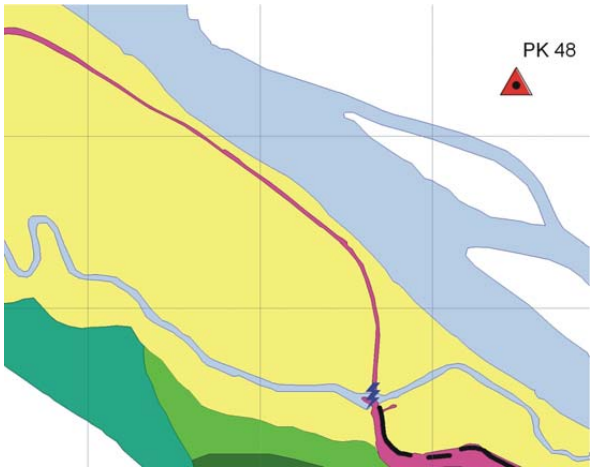
Sediment transported at this Site in the San Juan River: **7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Site located on Nicaraguan territory.

Related to Slope: **none** ***Related to Water Course:*** none



***Kondolf Point:* PK 49**

X-Coordinate: -84.084951 **Y-Coordinate:** 10.761729

***Maximum Sediment Production at this Site:* erosive water cause, estimation not possible at this moment**

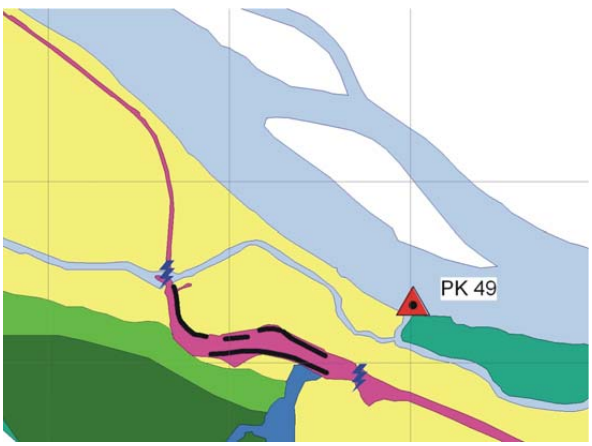
***Sediment transported at this Site in the San Juan River:* 7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **No data**

Description:

Site where the Caño Cureña (C-86) as well as another smaller water course (C-87) with erosive features flow into the San Juan River. Nevertheless, as seen in the last two photographs on the following page, during the day of the helicopter overflight the San Juan River exhibited a considerably higher sediment load in comparison with the incoming water course.

Related to Slope: **T-114, T-115**



Related to Water Course: **C-86, C-87**

Dr. Andreas Mende, Dr. Allan Astorga & Dr. Olivier Chassot *(September 2013)*

Kondolf Point: PK 50

X-Coordinate: -83.995491 **Y-Coordinate:** 10.760629

Maximum Sediment Production at this Site: ***40 t/year (estimation)***

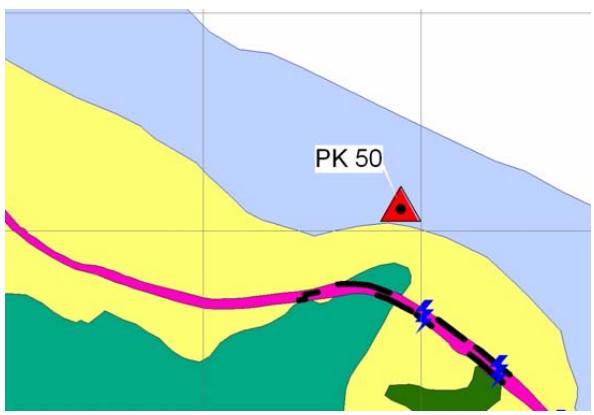
Sediment transported at this Site in the San Juan River: **7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.006%**

Description:

Most probably related to a fill slope site (T-153); sediment input to the San Juan River is buffered by the plain area between the fill slope and the river.

Related to Slope: **T-152** ***Related to Water Course:*** **none**



Kondolf Point: PK 51

X-Coordinate: -83.985908 **Y-Coordinate:** 10.761695

Maximum Sediment Production at this Site: ***0 t/year***

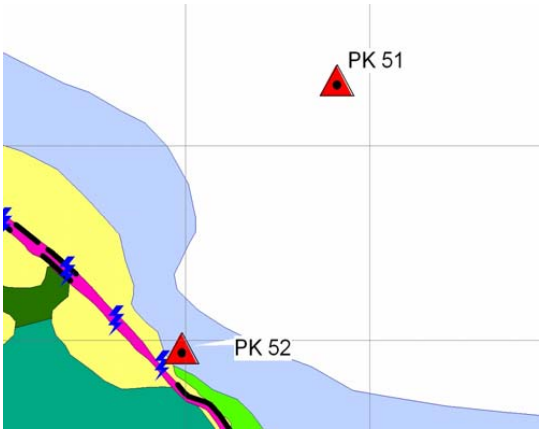
Sediment transported at this Site in the San Juan River: **7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Site located on Nicaraguan territory

Related to Slope: **none** ***Related to Water Course:*** **none**



***Kondolf Point:* PK 52**

X-Coordinate: -83.990118 **Y-Coordinate:** 10.754811

Maximum Sediment Production at this Site: ***< 3 t/year (estimation)***

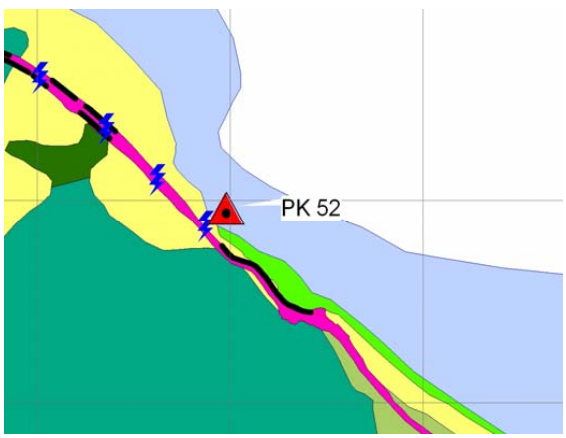
Sediment transported at this Site in the San Juan River: **7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Provisional drainage tube (C-98), some erosion and slight sediment flow.

Related to Slope: **none** ***Related to Water Course:*** **C-99**



***Kondolf Point:* PK 53**

X-Coordinate: -83.969122 **Y-Coordinate:** 10.736112

***Maximum Sediment Production at this Site:* < 1 t/year (estimation)**

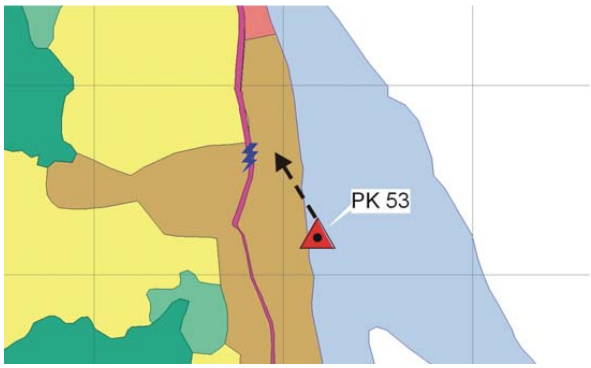
***Sediment transported at this Site in the San Juan River:* 7,753,350 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Provisional bridge over a small river (C-100) without any indicator for erosion or sediment flow into the San Juan River; the water of the C-100 exhibits a by far much lower degree of turbidity in comparison with the San Juan River.

Related to Slope: **none** ***Related to Water Course:*** **C-100**



Kondolf Point: PK 54

X-Coordinate: -83.918261 **Y-Coordinate:** 10.710488

Maximum Sediment Production at this Site: ***< 1 t/year (estimation)***

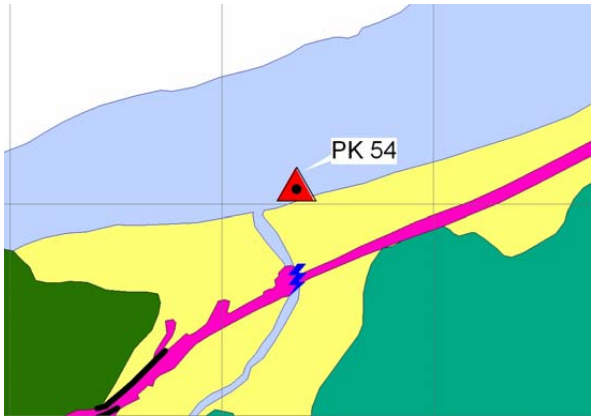
Sediment transported at this Site in the San Juan River: **8,949,300 t/year**

Maximum Sediment Production in relation to Sediment transported in the San Juan River: **0.000%**

Description:

Bridge over the Caño Negro (C-109), river edges stable and non-erosive, no visible indicators of sediment flow into the San Juan River.

Related to Slope: **none** ***Related to Water Course:*** **C-109**



1 CONCLUSIONS

The above data on the 54 sites specified in the Kondolf Report are summarized in Tables 1 and 2.

Table 1 gives an overview of all 54 sites regarding their maximum sediment production and the relation of this value in comparison with the sediment load at the corresponding site in question. In addition, Table 2 represents this data grouped by ranges of Maximum Sediment Production and the corresponding percentage in relation to the sediment transported in the San Juan River.

As determined in the study, 7 of the 54 sites (13%) indicated by Dr. Kondolf were actually located in Nicaragua rather than in Costa Rica. Those sites were therefore not assigned an absolute or proportional value of sediment input in this study. Additionally, in the case of 23 sites (42.6% of all sites), where Dr. Kondolf detected a direct flow of sediment from the border road into the San Juan River, it has not been possible to find any indicator or evidence to confirm this observation. In these cases photographs can prove that the border road does not affect in any way the San Juan River System. Therefore, in all, 30 sites (55.6%) of the 54 indicated by Dr. Kondolf lack factual basis.

5 sites lay in the range between 1 and 100 t/year of Maximum Sediment Production corresponding to 0.001 to 0.003% of the sediment transported in the San Juan River. These percentage values by themselves prove that these 4 sites can be fully ignored because the San Juan River is accustomed to transport extremely high sediment volumes.

7 sites (13%) fall in the range between 100 and 1000 t/year of Maximum Sediment Production corresponding to 0.001 to 0.025% of the sediment transported in the San Juan River. In the case of smaller river systems with much lower sediment loads, an additional sediment input within this range could provoke damages to some degree, but not with respect to the San Juan River due to its extremely high level sediment load, as shown by Gomez-Delgado et al. (2013).

The range between 1000 and 5600 t/year of Maximum Sediment Production (0.025 to 0.160% of the sediment transported in the San Juan River) counts for 9 sites (16.7%). Again, in the case of other river systems characterized by much lower sediment transportation rates in comparison to the San Juan River, sediment input of this dimension could generate serious problems. In the case of the San Juan River System the percentage values of 0.025 to 0.160% show that this river can handle much higher amounts of sediment and therefore there will be no significant damage to this river system as a whole. There are a small number of localised sites which have been impacted. For this reason it is recommended that Costa Rica continues with the so far successful actions and measures to mitigate erosion and sedimentation.

Kondolf Site	Maximum Sediment Production[1]	Sediment transported in the San Juan River[2]	Maximum Sediment Production in relation to Sediment transported in the San Juan River
1	740 t/year	**3,362,000 t/year** (Mojón II to Río Infiernillo)	0.022 %
2	360 t/year		0.011 %
3	0 t/year		0.000 %
4	< 1 t/year		0.000 %
5	260 t/year		0.008 %
6	1,200 t/year		0.035 %
7	< 1 t/year		0.000 %
8	340 t/year		0.010 %
9	0 t/year		0.000 %
10	< 1 t/year		0.000 %
11	0 t/year		0.000 %
12	4,000 t/year		0.119 %
13	< 1 t/year		0.000 %
14	< 1 t/year		0.000 %
15	< 1 t/year		0.000 %
16	< 1 t/year		0.000 %
17	300 t/year		0.009 %
18	5,580 t/year	**3,559,500 t/year** (Río Infiernillo to Río San Carlos)	0.157 %
19	2,160 t/year		0.003 %
20	0 t/year		0.047 %
21	2,070 t/year		0.058 %
22	< 1 t/year		0.000 %
23	< 1 t/year		0.000 %
24	0 t/year		0.049 %
25	2,250 t/year		0.063 %
26	4,500 t/year (includes 27)		0.126 %
27	See Nº 26		0.126 %
28	3,400 t/year		0.095 %
29	5,000 t/year		0.141 %
30	< 1 t/year		0.000 %
31	50 t/year		0.001 %
32	< 1 t/year		0.000 %
33	90 t/year		0.002 %
34	< 1 t/year		0.000 %
35	< 1 t/year		0.000 %
36	No data !!		No data !!
37	890 t/year		0.025 %
38	390 t/year		0.011 %
39	< 1 t/year		0.000 %
40	< 1 t/year		0.000 %
41	30 t/year		0.001 %
42	0 t/year		0.000 %
43	< 1 t/year	**7,753,350 t/year** (Río San Carlos to Río Sarapiquí)	0.000 %
44	< 1 t/year		0.000 %
45	< 1 t/year		0.000 %
46	< 1 t/year		0.000 %
47	< 1 t/year		0.000 %
48	0 t/year		0.000 %
49	No data !!		No data !!
50	40 t/year		0.001 %
51	0 t/year		0.000 %
52	< 3 t/year		0.000 %
53	< 1 t/year		0.000 %
54	< 1 t/year	**8,949,300 t/year** (Río Sarapiquí to Delta Costa Rica)	0.000 %

Table 1: Resume of the collected data for the 54 sites mentioned by Kondolf et al. (2012): sites marked in light green refer to those locations where no sediment input could be detected, sites marked in light orange are those where a possible sediment input to the San Juan River has been found), sites marked in grey are those located in Nicaragua; ([1]): based upon the data from Mende & Astorga (2013); ([2]): based upon the data from Gomez-Delgado et al. (2013).

Maximum Sediment Production[1]	Maximum Sediment Production in relation to Sediment transported in the San Juan River[2]	Number of Sites mentioned by Kondolf et al (2012)
Sites located in Nicaragua	**0.000 %**	**7**
0 - 1 t/year	**0.000 %**	**23**
1 -100 t/year	**0.001 – 0.003 %**	**5**
100 – 1000 t/year	**0.003 – 0.025%**	**7**
1000 – 5600 t/year	**0.025 – 0.160%**	**9**
No data / excluded ([3])	**- - - - -**	**3**
Sum		***54***

Table 2: Data for the 54 sites mentioned by Kondolf et al. (2012) grouped based on ranges of Maximum Sediment Production and the according percentage in relation to Sediment transported in the San Juan River; ([1]): based on data from Mende & Astorga (2013) ; ([2]): based on data from Gomez-Delgado et al. (2013); ([3]): site 27 has been excluded because its sediment production is included in the value of site 26.

2 REFERENCES

Astorga, A. & Mende, A. (2013): *Ruta 1856*Route 1856: *Analysis of the Change in Land Use.* San José, Costa Rica.

Gomez-Delgado, F., Leitón-Montero, J.J. & Aguilar-Cabrera, C.A. (2013). *Report on hydrology and sediments for the Costa Rican river basins draining to the San Juan River*. San José, Costa Rica: Instituto Costarricense de Electricidad.

Kondolf, G. M., Hagans, D., Weaver, B & Weppner, E. (2012): *Environmental Impacts of Juan Rafael Mora Porras Route 1856, Costa Rica, on the Río San Juan, Nicaragua.*

Mende, A. & Astorga, A. (2013): *Inventory of Slopes and Water Courses related to the Border Road Nº 1856 between Mojón II and Delta Costa Rica.* San José, Costa Rica.

ANNEX 6

Dr. Andreas Mende and Dr. Allan Astorga

Inventory of Slopes and Water Courses related to the Border Road Nº 1856 between Mojón II and Delta Costa Rica

September 2013

Inventory of Slopes and Water Courses related to the Border Road Nº 1856 between Mojón II and Delta Costa Rica

Elaborated by:

Dr. Andreas Mende
International Expert in Geographic Information Systems and Remote Sensing

In cooperation with:
Dr. Allan Astorga
International Expert in Environmental Geology and Land Management

Presented to:

***Ministry of Foreign Affairs* - Costa Rica**

San José - Costa Rica
October 2013

1 INTRODUCTION

This report provides a complete inventory of all cut slopes, fill slopes, and watercourse intersections (crossings) along Route 1856 between the Mojón II, where the border road first approaches the San Juan River, and Delta Costa Rica, where it ends.

Applying data on erosion depths and rates of land surface lowering due to sheet, rill, landslide and gully erosion reported in UCR (2013), by Oreamuno Vega, M. Eng. and Roberto Villalobos Herrera at the University of Costa Rica, we estimated the sediment yields from all the cut and fill slopes that exist along the border road between Mojón II and Delta Costa Rica. The sediment yields were, in turn, passed to Federico Gómez Delgado, Juan José Leitón Montero and Carlos Aguilar at the Costa Rican Institute of Electricity, Centre for Engineering Studies, Department of Hydrology. They used the yields, together with calculations of sediment yields due to sheet and rill erosion of the road bed and other disturbed areas, to estimate overall erosion and sediment delivery from Route 1856 to the San Juan River system (ICE 2013).

2 METHODOLOGY

The inventory of cut and fill slopes, and watercourse intersections and crossings was undertaken between April and August 2013. It is based upon extended field work, navigation on Costa Rican rivers and helicopter over flights, complemented by examination of high resolution satellite images.

The following guidelines were used as a basis for building the inventory:

- A unique identification code was assigned to each feature (**C-1**, **C-2** etc. for watercourse intersections/crossings and **T-1**, **T-2** etc. for cut and fill slopes (Spanish Talud)), in order to create a complete register and uniform nomenclature to be used in this and all future studies.
- Attribute data for slopes and watercourses were collected and entered on specially designed data record sheets in order to guarantee standardized and complete data records (see Figures 1 and 2).

Identification Code:									
Date:		**Date:**				**Date:**			
General Data:									
Slope Type		***Puntos de GPS:***		**Height:**		**Location** (in flow direction of San Juan River)			
1	Fill Slope	*Beginning:*		Average Height (m):		1	Right		
2	Cut Slope	*End:*		Maximum Height (m):		2	Left		
		Additional Location:							
Characteristics:									
Mitigation Measures:		*Erosion*		*Geology:*					
1	None	1	None	1	Ophiolite Complex of Tiricias				
2	Geotextiles	2	Sheet erosion	2	Turbidites from the Eocene/Paleocene				
3	Drainage Control	3	Rills	3	Volcanic and Volcaniclastic rocks of Tertiary age				
4	Stabilization by Terraces	4	Gullies	4	Volcanic Rocks of Quaternary age				
5	Sowed Vegetation	5	Land Slides	5	Volcaniclastic Rocks of Quaternary age				
6	Natural Vegetation			6	Coarse Volcaniclastic Breccias				
				7	Land Fill				
Erosion:									
Sheet Erosion		***Rills***		***Gullies***		***Land Slides***			
	% affected area		% affected area		% affected area		% affected area		
					Depth (m)		Length (m)		
					Width (m)		Height (m)		
Geology / Geomorphology:									
Comments:									

Figure 1: Data sheet used for the collection of field data in the case of slopes.

- Attribute data have been stored in an ACCESS database especially designed for this project and purpose. Second degree normalization of all information in the database has been performed to maximize the capacity for analysis. The data in the database are spatially referenced within an ArcMAP GIS environment. This was achieved using an OLE DB Connection, based upon unique identification codes for each slope and watercourse.
- The locations of each feature were established in the field using a high precision GPS, with an average accuracy of 1 m. In the case of slopes, the GPS coordinates of the start and end points of the feature were recorded, whereas for

watercourses the intersection point(s) with the Border Road were recorded. In the case of bridges with a length greater than 5 m, the start and end points of the structure were recorded using the GPS.

- The present states of all slopes and watercourses were documented using digital photographs. Photograph numbers and descriptions are included in the ACCESS data base.

Identification Code:							
Date:		**Location:**			**Staff Member:**		
General Data:							
Land Fill:		*GPS Data:*			Drainage Tube:		
0	Not present		*Intersection Point (1):*			Diameter (m):	
2	Present		*Intersection Point (2):*			Horizontal Orientation (º):	
			Additional Location:				
Characteristics:							
Type of Structure			*Present Technical State:*			*Sedimentation:*	
1	Closed Land Fill		1	Closed		0	Not present
2	Land Fill with Drainage Tube		2	Provisional		1	Present
3	Land Fill with Bridge		3	Improved			
4	Land Fill with Tree-Trunks		4	Appropriate		*Erosion:*	
5	Bridge without Land Fill		5	Broken		0	Not present
6	Without any Construction					1	Present
Geology / Geomorphology:							
Comments:							

Figure 2: Data sheet used for the collection of field data in the case of water course intersections and crossings.

3 DATA COLLECTION

This section reports the data sets collected for slopes and watercourses (see the record sheets used for field data collection in Figures 1 and 2).

Administrative data for each feature comprise the *Unique Identification Code* for each feature, the date of the field visit, a short description of the location and the name of the person executing field data collection, together with the GPS coordinates.

For water course intersections and crossings, records include the ***Type Of Structure*** *(options: Closed Land Fill, Land Fill with Drainage Tube, Land Fill with Bridge, Land Fill with Tree-Trunks, Bridge without Land Fill, Without any Construction)* and the ***Present Technical State*** *(options: Closed, Provisional, Improved, Appropriate, Broken, Without any Construction)*. In addition, the presence/absence of ***Sedimentary/Erosive Processes*** and the potential ***Use of Land Fills*** for the crossing are recorded. Free text fields for descriptions of geological and/or geomorphological features and any general comments complete the record.

For slopes, records include the ***Type of Slope*** (*options:* fill or cut slope), the average and maximum height of the slope and which side of the road the feature is on (*options:* left or right with respect to the downstream direction of the adjacent San Juan River). Slope heights were estimated visually in the field so that data collection could be completed within a reasonable time span.

Specific data for slopes include ***Erosion Features*** (*options: None, Sheet Erosion, Rills, Gullies, Land Slides*) and ***Geology - Stratigraphic Unit*** (*options: Ophiolite Complex of Tiricias, Turbidites of Eocene/Paleocene age, Volcanic and Volcaniclastic rocks of Tertiary age, Volcanic Rocks of Quaternary age, Volcaniclastic Rocks of Quaternary age, Coarse Volcaniclastic Breccias, Land Fill*).

Field observations also included estimating the ***Proportion of the Feature covered by each type of Erosion*** (option: *percentage of the total area of the slope*). It was observed that the areas affected by each type of erosion did not overlap, so the sum of the percentages of the attribute classes (*None, Sheet Erosion, Rills, Gullies, Land Slides)* always add up to 100% of the total area of the slope.

Finally, the presence of any ***Mitigation Measures*** was noted (*options: None, Geotextiles, Drainage Control, Stabilization by Terraces, Sowed Vegetation, Natural Vegetation, Sediment Traps*). As in the case of watercourses, free text fields for descriptions of geological and/or geomorphological features and other comments in general complete the record.

4 SPATIAL DISTRIBUTION OF SLOPES AND WATER COURSES

In Figure 3 we present an overview map showing the locations of all slopes and water course intersections along the Road between Mojón II and Delta Costa Rica. Tables 1 and 2 provide summary information on the spatial distribution of slopes and watercourses grouped into four segments of the Road:

(1) Mojón II to Río Infiernito (13.8 km),

(2) Río Infiernito to Río San Carlos (27.6 km),

(3) Río San Carlos to Río Sarapiquí (43.6 km) and

(4) Río Sarapiquí to Delta Costa Rica (22.6 km).

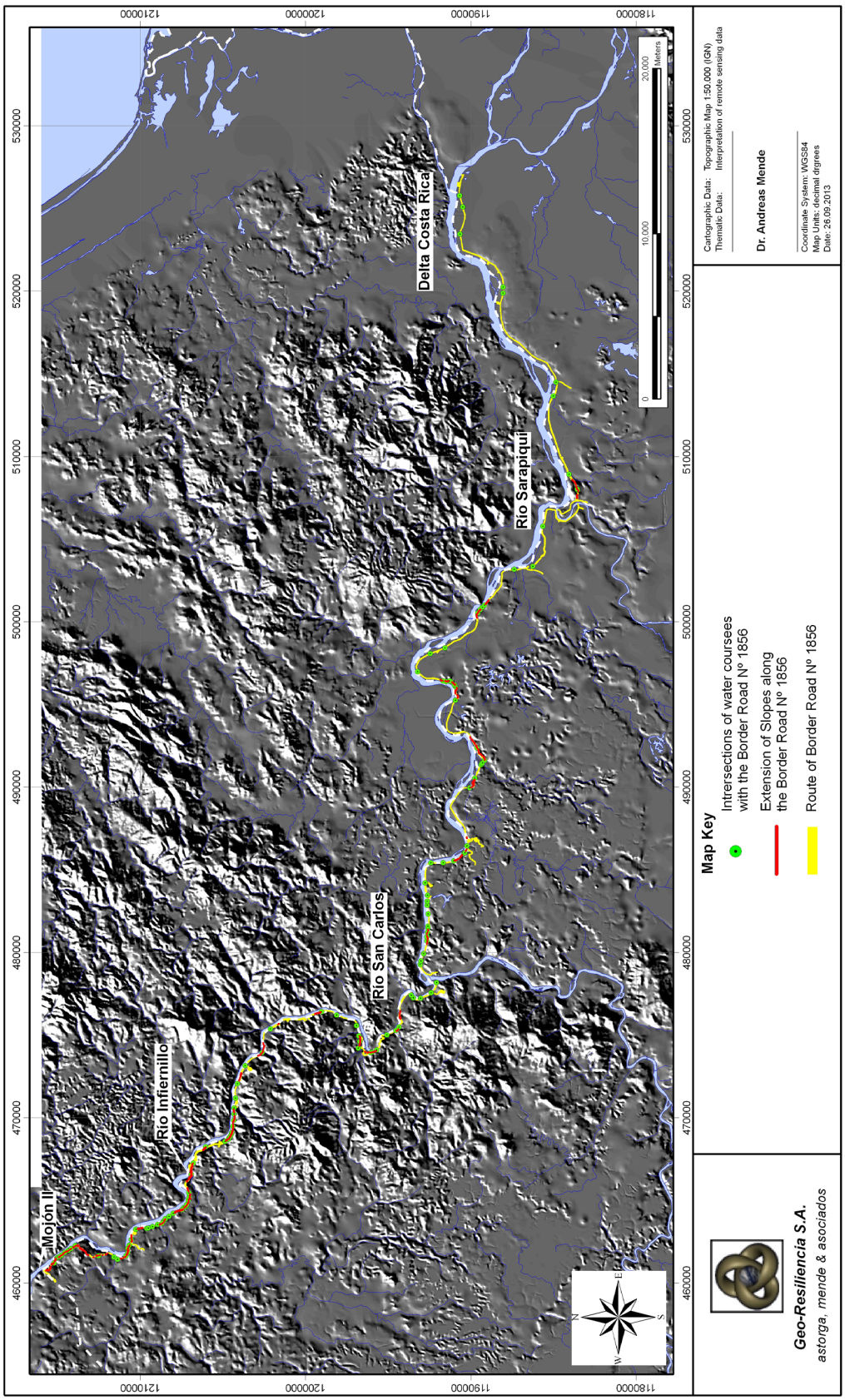
The map in Figure 3, together with the information in Tables 1 and 2, reveal a clear pattern in the spatial distribution and density of slopes and watercourse intersections, and this is discussed below.

The number and density of watercourse intersections are highest in Segment 1 (34 watercourses, 2.5 intersections kilometre). Segment 1 also contains the greatest length and highest proportion of slopes (length 9.4 km, which is 68% of the length of the Road between Mojón II and Río Infiernito). Segment 2 also exhibits relatively high watercourse numbers and densities (34 watercourses, 1.3 intersections per kilometre). In Segment 2, slopes are found along 7.9 km of the Road, which is 29% of the length of the Road in this segment.

In Segment 3 there are 43 watercourses, but the intersections are more widely spaced because this segment is longer (43.6 km), yielding just 1 intersection per kilometre. Slopes are found along 6.7 km of the Road in this segment, which constitutes 15% of the 43.6 km length of the Road in this segment.

There are only 10 watercourses in Segment 4, from the Sarapiquí River to Delta Costa Rica, meaning that the density of intersections is only 0.4 per kilometre. Similarly, there are only 10 slopes in this low relief segment, occupying just 5% of the length of the Road.

Figure 3: **Overview map with the locations of all slopes and water course intersections along the 1856 Road between Mojón II and Delta Costa Rica**


Mojón II
Rio Infiernillo
Rio San Carlos
Rio Sarapiquí
Delta Costa Rica
460000
470000
480000
490000
500000
510000
520000
530000
1180000
1190000
1200000
1210000
0
10,000
20,000
Meters
N
E
S
W
Map Key
Intrersections of water coursees with the Border Road Nº 1856
Extension of Slopes along the Border Road Nº 1856
Route of Border Road Nº 1856
Geo-Resiliencia S.A.
astorga, mende & asociados
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 26.09.2013

Road Section	Section Length (km)	Slopes (number)	Slopes (total length)	Slopes (percentage of segment road length)
Section 1 - Mojón II to Río Infiernito	13.8 km	63	9.4 km	68 %
Section 2 - Río Infiernito to Río San Carlos	27.6 km	53	7.9 km	29 %
Section 3 - Río San Carlos to Río Sarapiquí	43.6 km	64	6.7 km	15 %
Section 4 - Río Sarapiquí to Delta Costa Rica	22.6 km	8	1.1 km	5 %
Sum	107.6 km	188	25.1 km	

Table 1: Spatial distribution of slopes along the border road Nº 1856 in function of 4 established road segments.

Road Section	Section Length (km)	Water Courses (number)	Number of Water Courses per Kilometre
Section 1 - Mojón II to Río Infiernito	13.8 km	34	2.5
Section 2 - Río Infiernito to Río San Carlos	27.6 km	35	1.3
Section 3 - Río San Carlos to Río Sarapiquí	43.6 km	43	1.0
Section 4 - Río Sarapiquí to Delta Costa Rica	22.6 km	10	0.4
Sum	107.6 km	122	

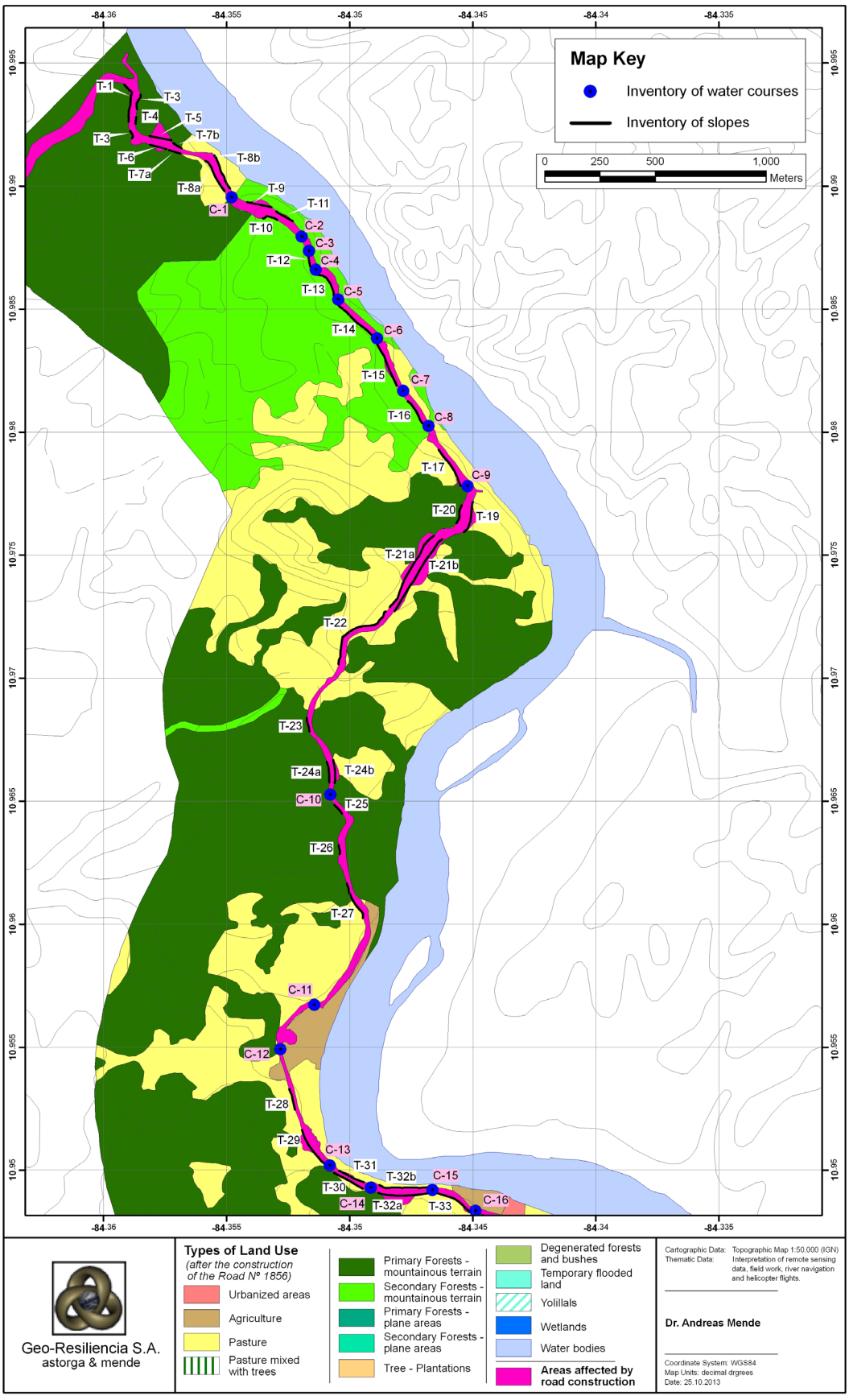
Table 2: Spatial distribution of water courses along the border road Nº 1856 in function of 4 established road segments.

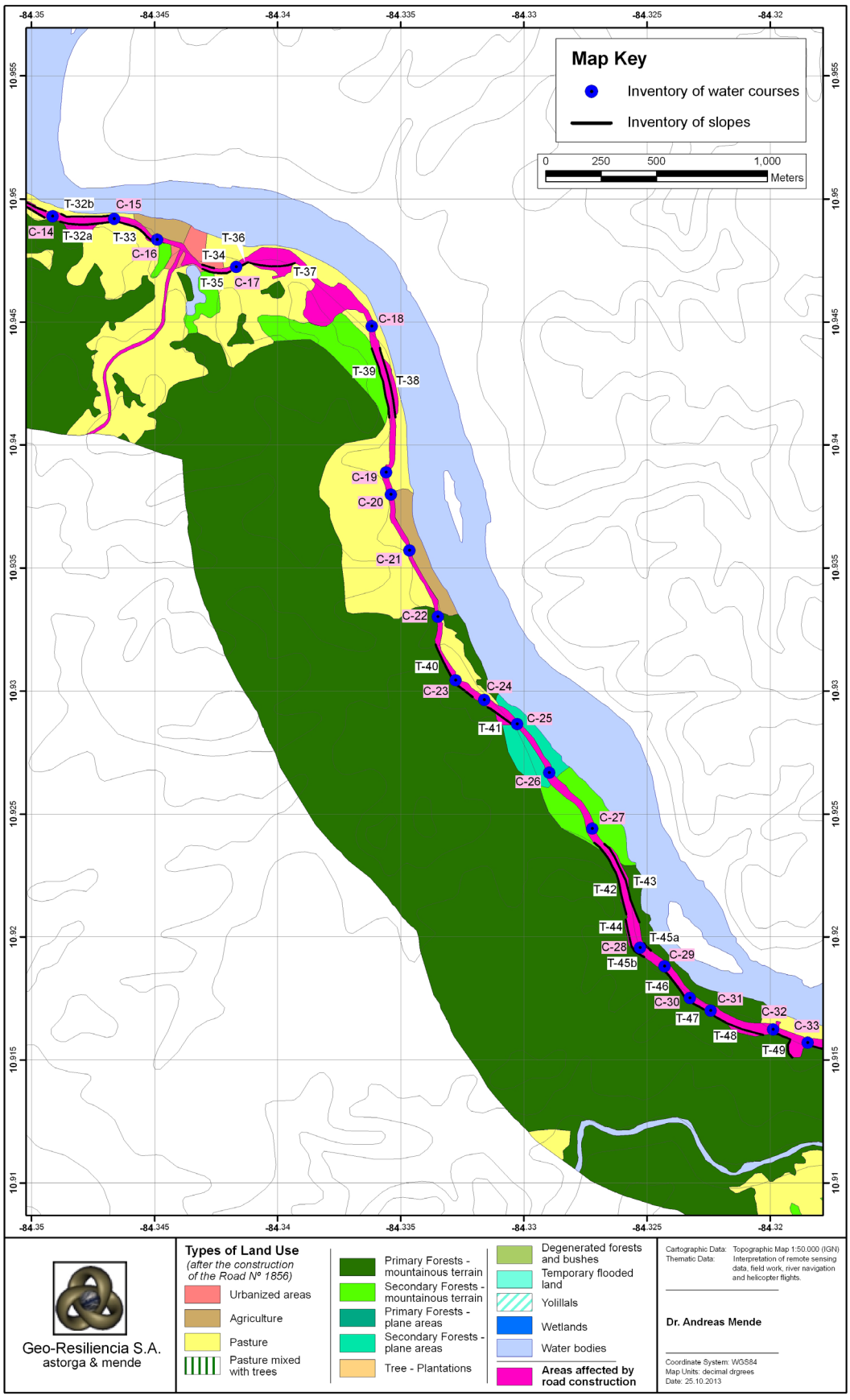
In conclusion, both the numbers and densities of watercourse intersections, and the lengths and proportions of slopes decrease with distance from Mojón II. The spatial distributions of these features are such that they are highly concentrated in segments 1 and 2. Segment 3 has a lower but moderate concentration of watercourse and slope features, while these are rare in Segment 4.

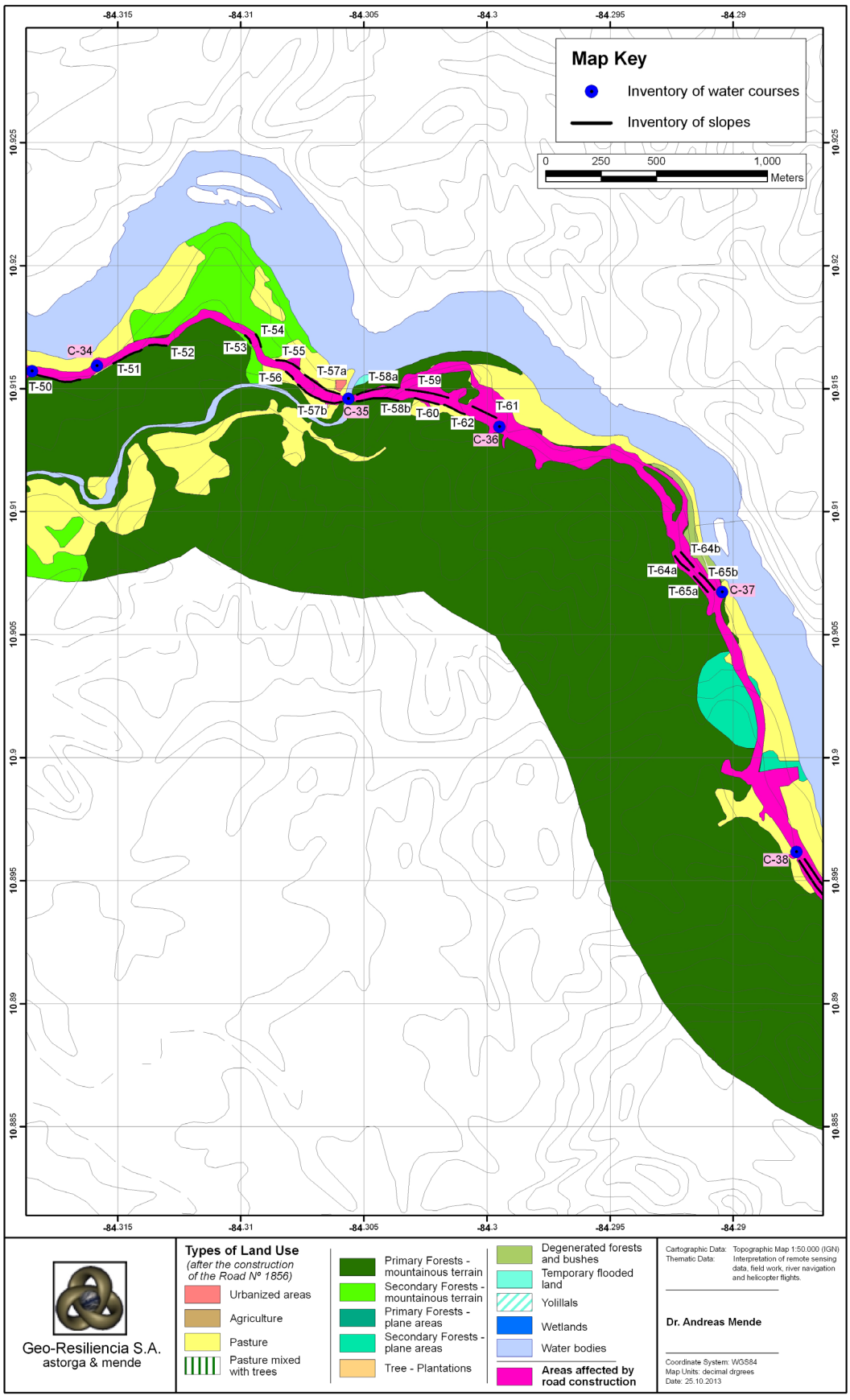
5 DETAILED MAP SET SHOWING SLOPES AND WATER COURSES ALONG ROUTE 1856

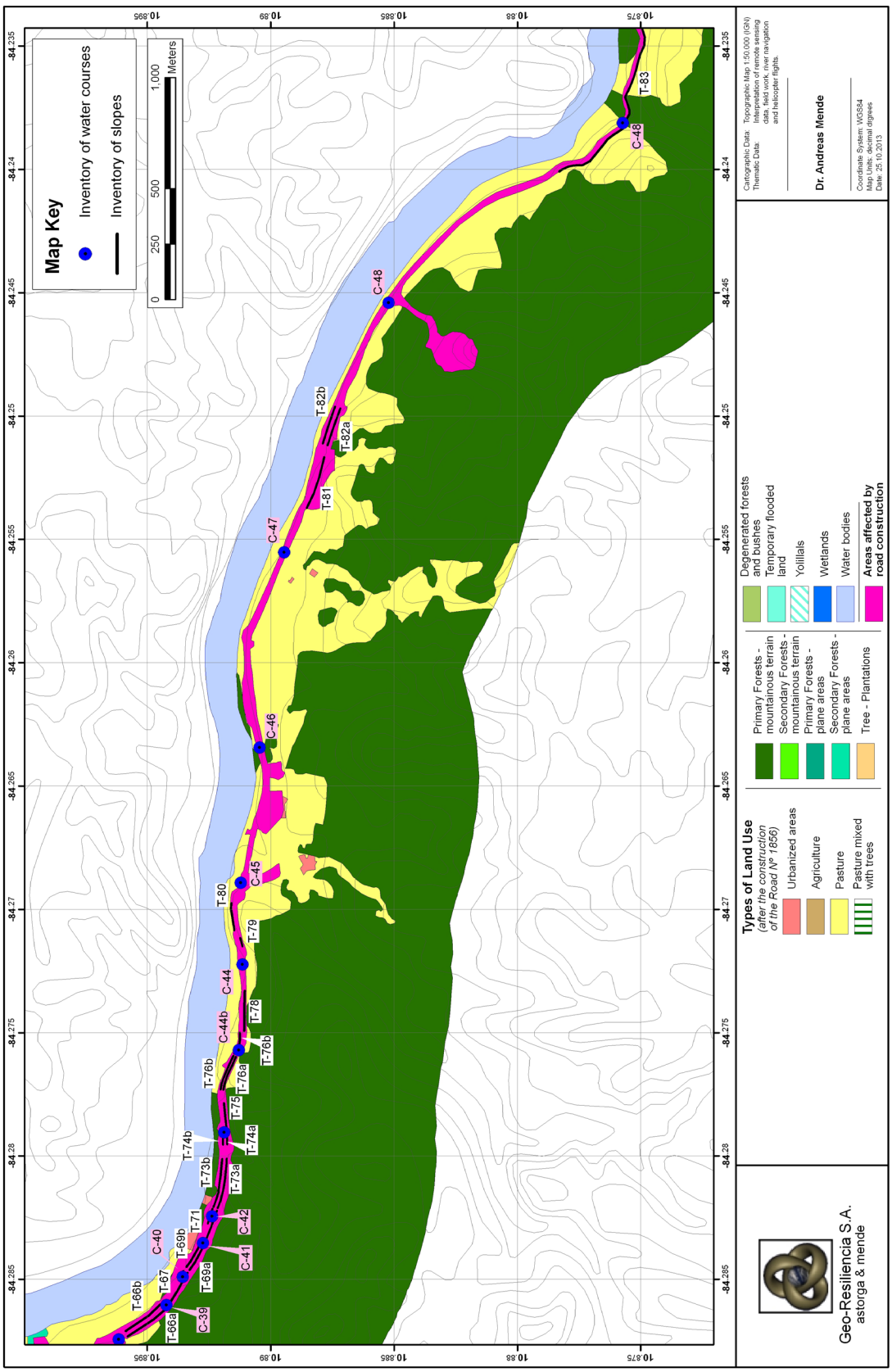
To provide detailed cartographic information regarding all watercourse intersections and slopes along the Route 1856 between Mojón II and Delta Costa Rica, we made a set of 16 detailed maps at a scale of 1:15.000. These maps show the extents of all slopes and locations of all watercourse intersections along the Road. This map set is based on the land use change maps produced earlier by Astorga & Mende (2013).

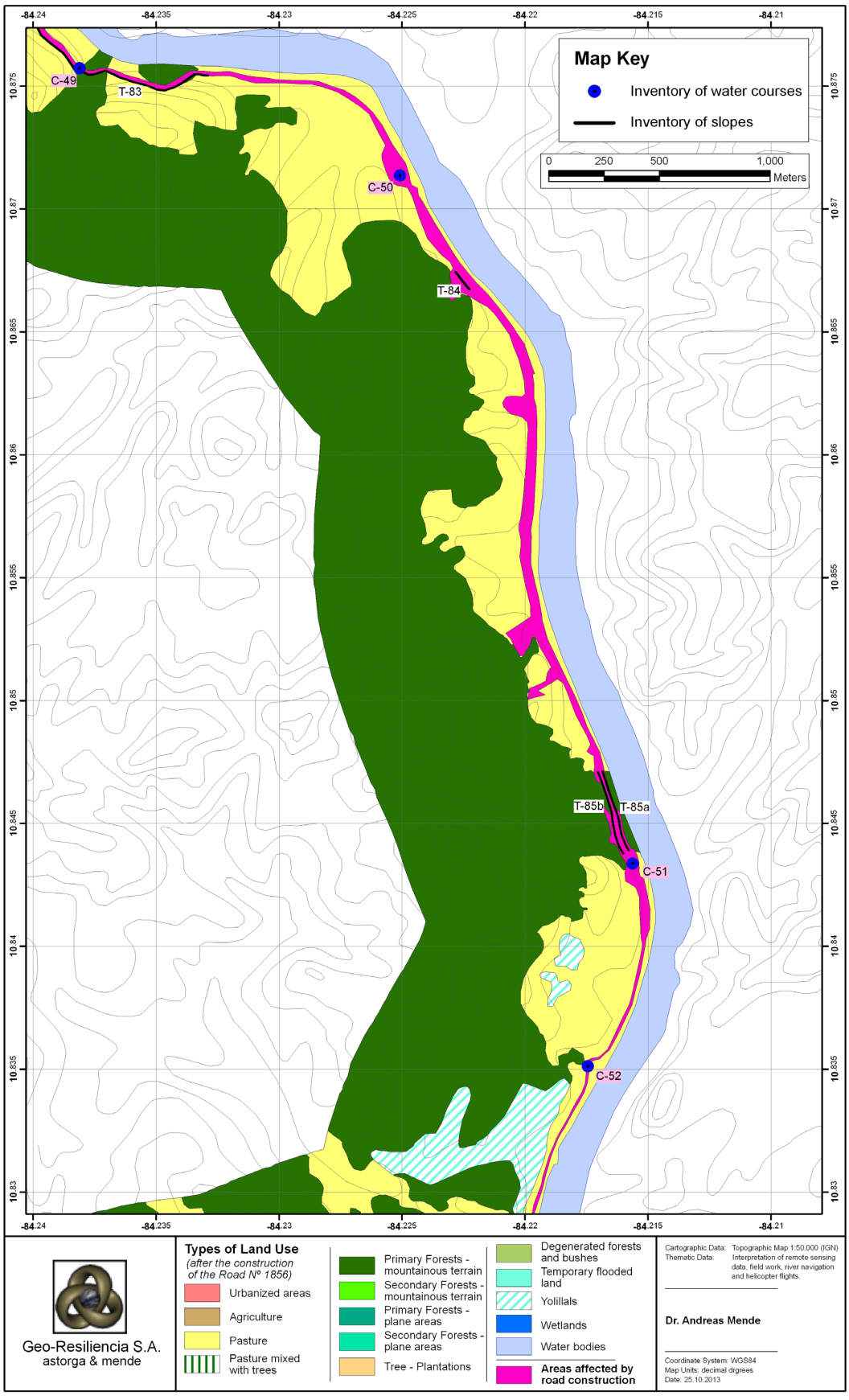
Detailed Set of 16 Maps showing Slopes and Water Courses along Route 1856 between Mojón II and Delta Costa Rica

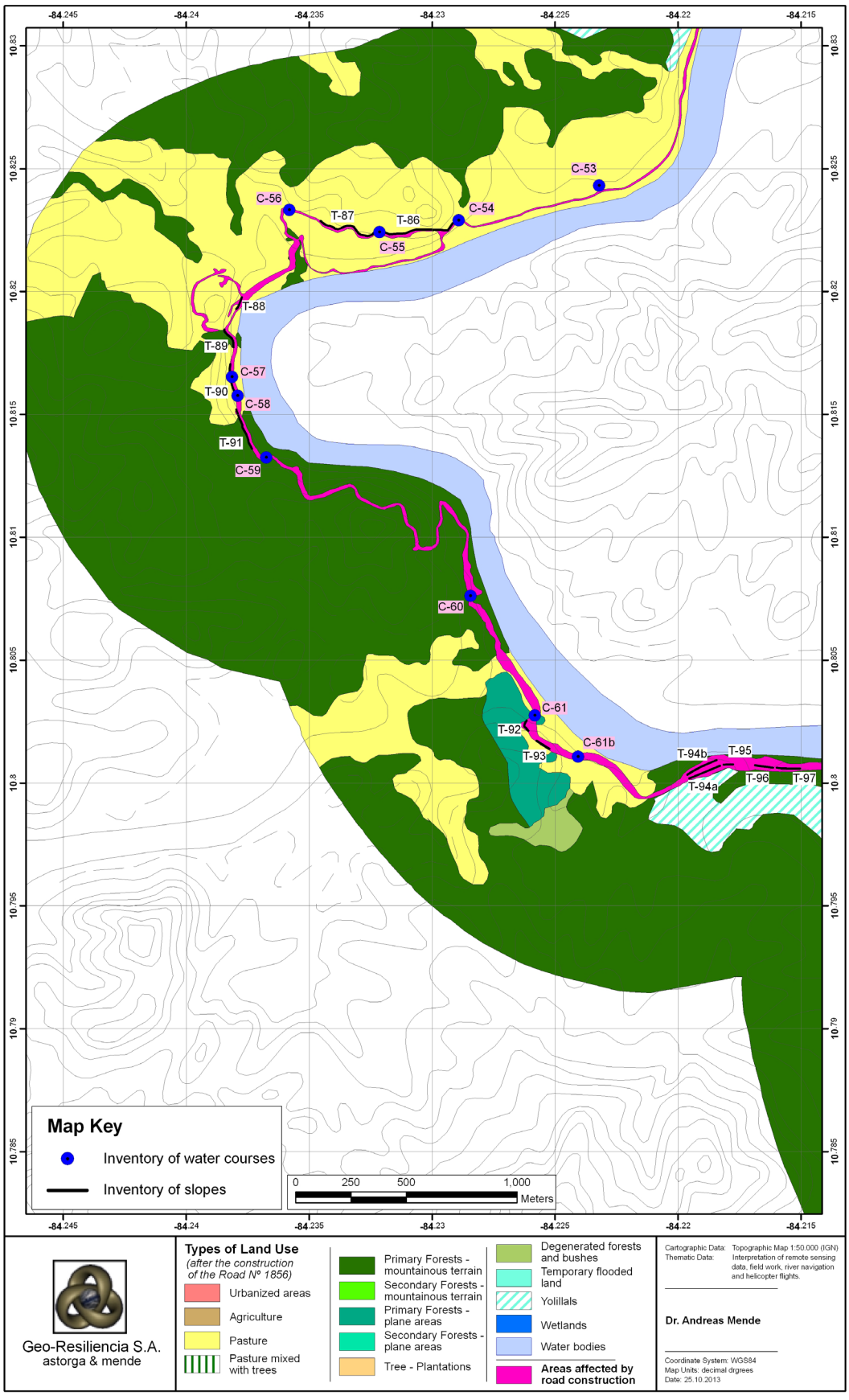

Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1,000
Meters
-84.36
-84.355
-84.35
-84.345
-84.34
-84.335
10.995
10.99
10.985
10.98
10.975
10.97
10.965
10.96
10.955
10.95
T-1
T-3
T-4
T-5
T-7b
T-3
T-6
T-7a
T-8b
T-8a
T-9
C-1
T-11
T-10
C-2
C-3
T-12
C-4
T-13
C-5
T-14
C-6
T-15
C-7
T-16
C-8
T-17
C-9
T-20
T-19
T-21a
T-21b
T-22
T-23
T-24a
T-24b
C-10
T-25
T-26
T-27
C-11
C-12
T-28
T-29
C-13
T-31
T-32b
C-15
T-30
C-14
T-32a
T-33
C-16
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 25.10.2013

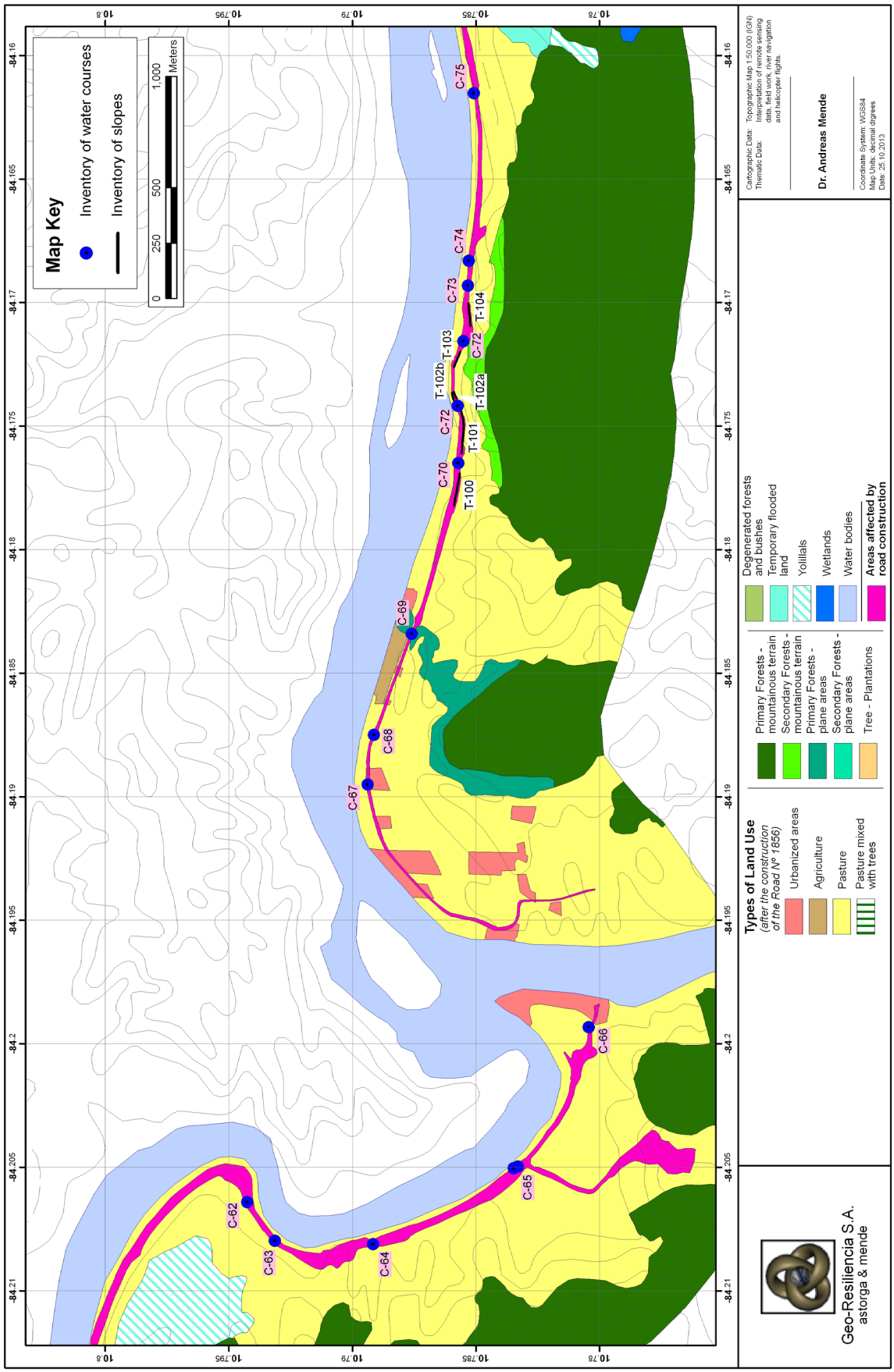

Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1,000
Meters
-84.35
-84.345
-84.34
-84.335
-84.33
-84.325
-84.32
10.955
10.95
10.945
10.94
10.935
10.93
10.925
10.92
10.915
10.91
T-32b
C-15
C-14
T-32a
T-33
T-36
C-16
T-34
T-37
T-35
C-17
C-18
T-39
T-38
C-19
C-20
C-21
C-22
T-40
C-23
C-24
C-25
T-41
C-26
C-27
T-42
T-43
T-44
T-45a
C-28
C-29
T-45b
T-46
C-30
C-31
C-32
T-47
C-33
T-48
T-49
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 25.10.2013

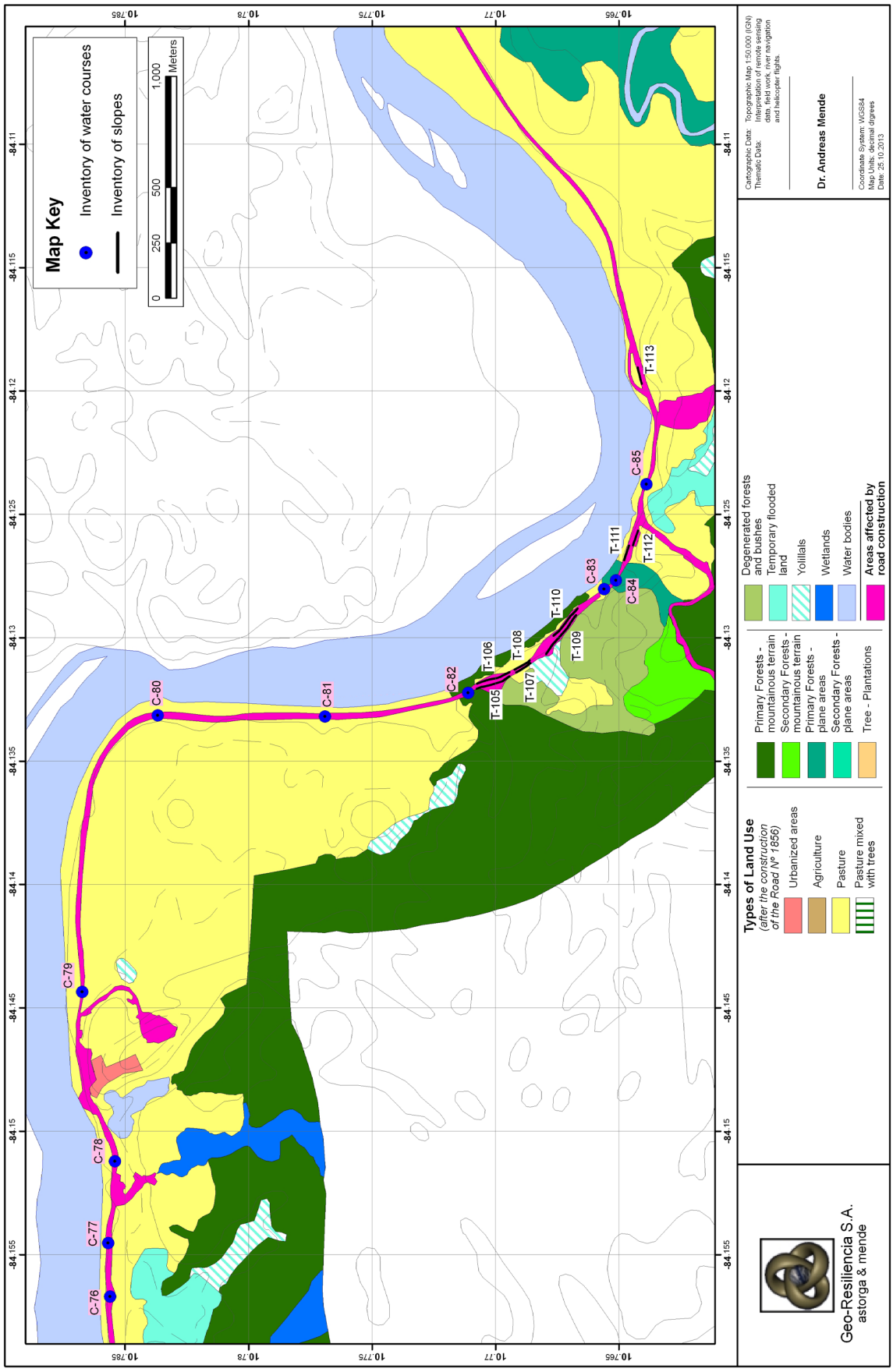

Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1,000
Meters
-84.315
-84.31
-84.305
-84.3
-84.295
-84.29
10.925
10.92
10.915
10.91
10.905
10.9
10.895
10.89
10.885
C-34
T-50
T-51
T-52
T-53
T-54
T-55
T-56
T-57a
T-57b
C-35
T-58a
T-58b
T-59
T-60
T-61
T-62
C-36
T-64a
T-64b
T-65a
T-65b
C-37
C-38
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 25.10.2013

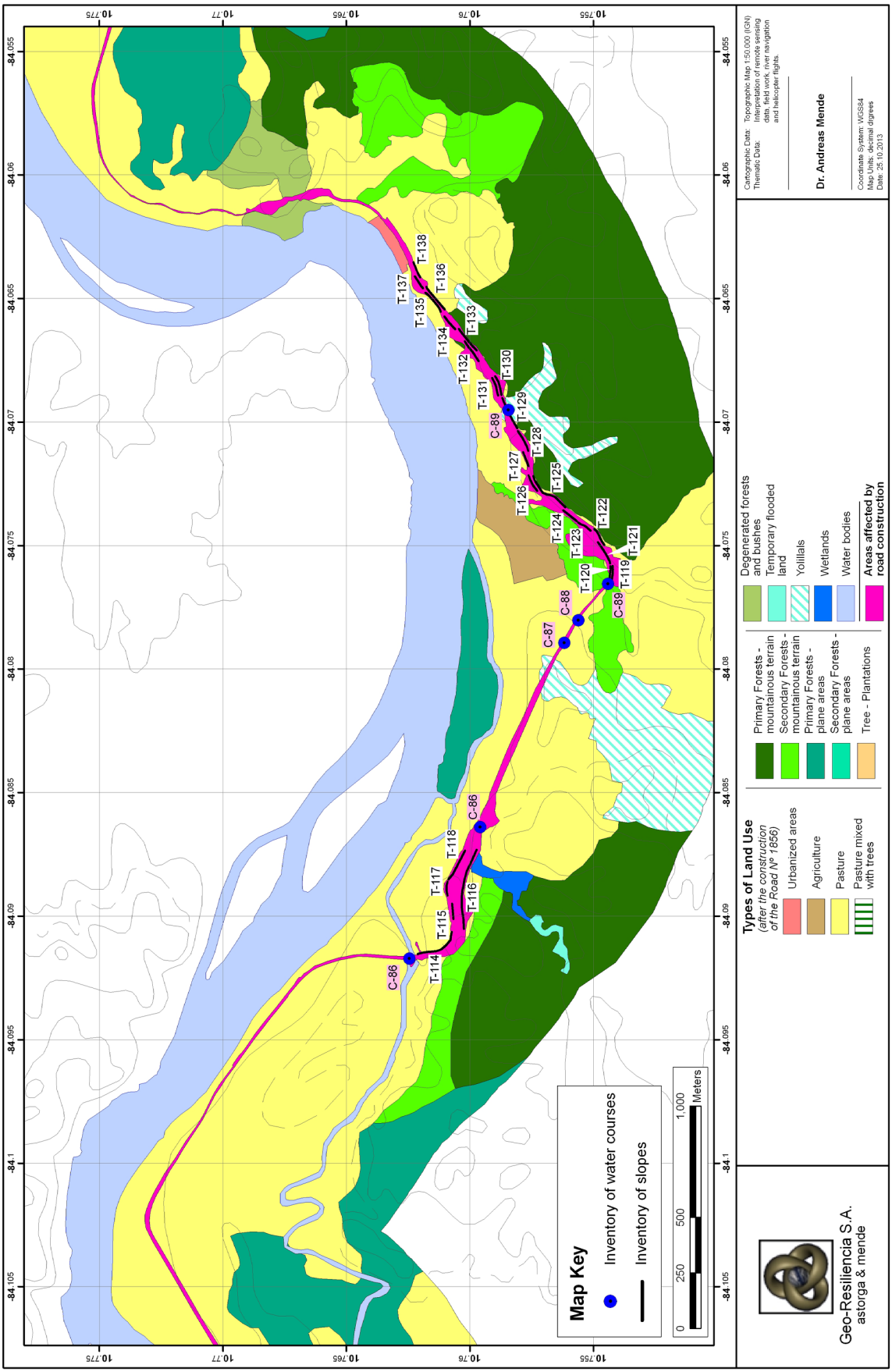

Map Key
Inventory of water courses
Inventory of slopes
0
250
500
1,000
Meters
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 23.10.2013
C-39
C-40
C-41
C-42
C-44
C-44b
C-45
C-46
C-47
C-48
T-66a
T-66b
T-67
T-69a
T-69b
T-71
T-73a
T-73b
T-74a
T-74b
T-75
T-76a
T-76b
T-78
T-79
T-80
T-81
T-82a
T-82b
T-83

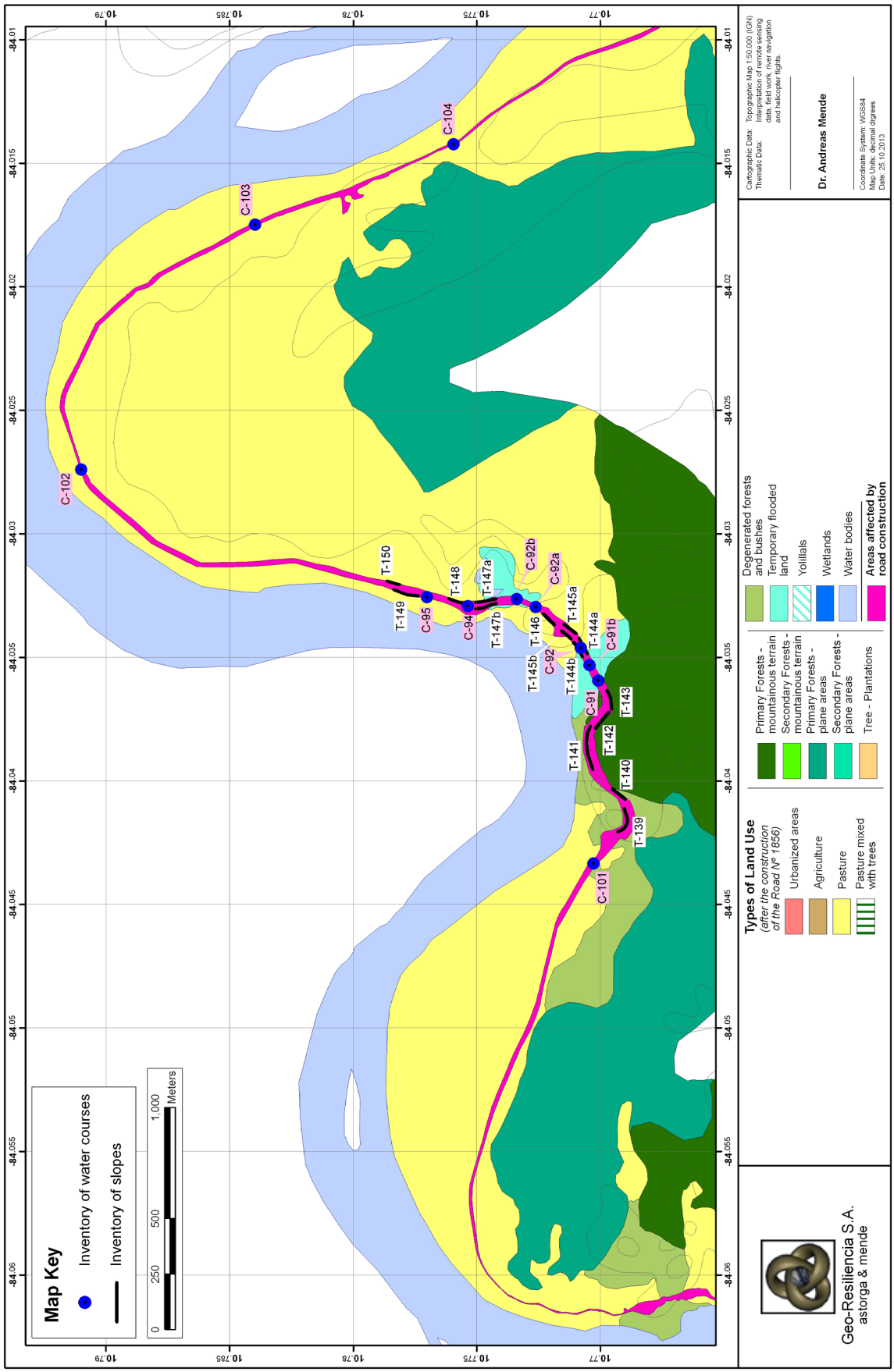

Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1,000
Meters
C-49
T-83
C-50
T-84
T-85b
T-85a
C-51
C-52
-84.24
-84.235
-84.23
-84.225
-84.22
-84.215
-84.21
10.875
10.87
10.865
10.86
10.855
10.85
10.845
10.84
10.835
10.83
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 25.10.2013

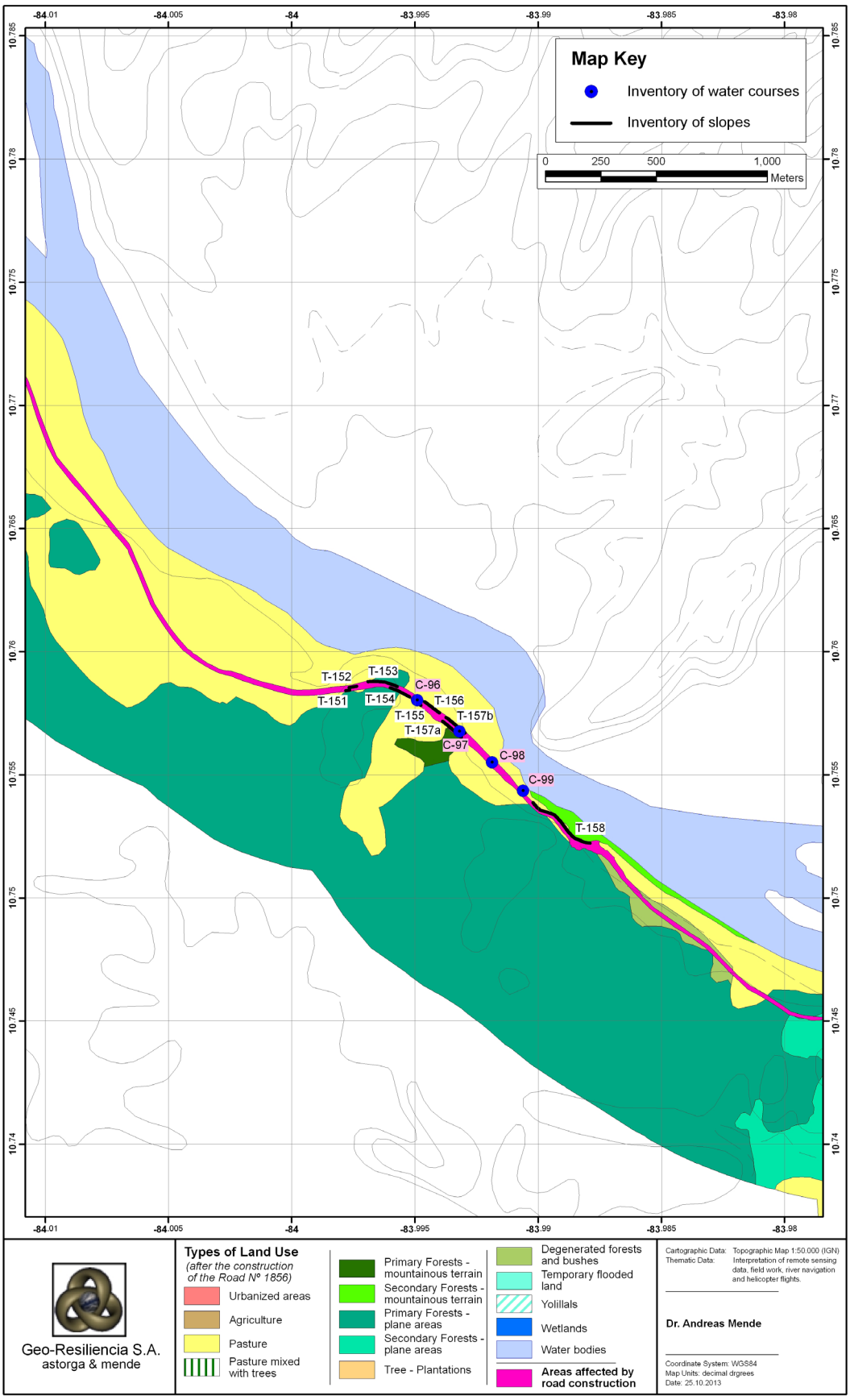

-84.245
-84.24
-84.235
-84.23
-84.225
-84.22
-84.215
10.83
10.825
10.82
10.815
10.81
10.805
10.8
10.795
10.79
10.785
C-53
C-54
C-55
C-56
T-86
T-87
T-88
T-89
C-57
T-90
C-58
T-91
C-59
C-60
C-61
T-92
T-93
C-61b
T-94a
T-94b
T-95
T-96
T-97
Map Key
Inventory of water courses
Inventory of slopes
0
250
500
1,000
Meters
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 25.10.2013

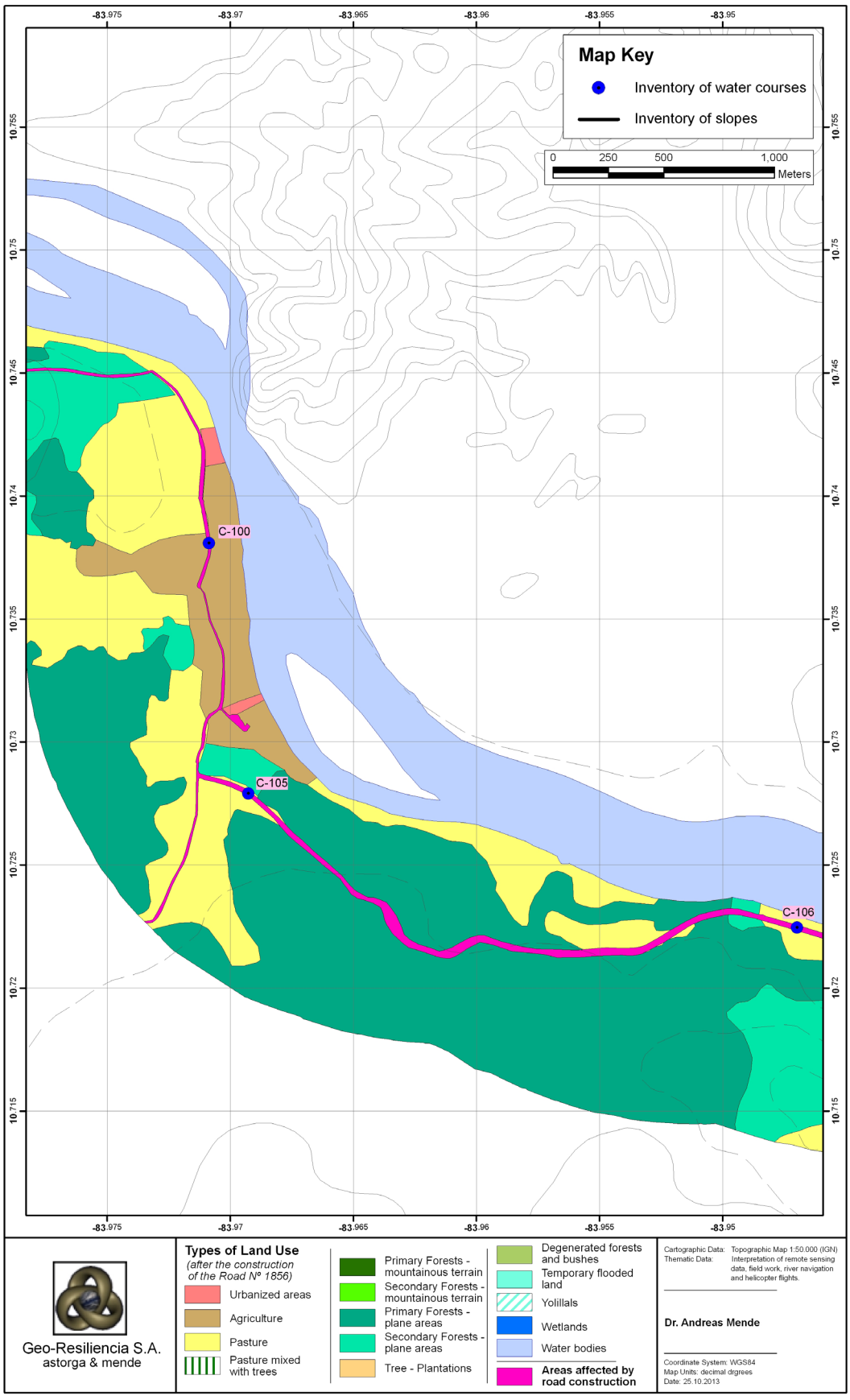

Map Key
Inventory of water courses
Inventory of slopes
0
250
500
1.000
Meters
C-62
C-63
C-64
C-65
C-66
C-67
C-68
C-69
C-70
C-72
T-100
T-101
T-102a
T-102b
T-103
C-72
T-104
C-73
C-74
C-75
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 25.10.2013
Geo-Resiliencia S.A.
astorga & mende

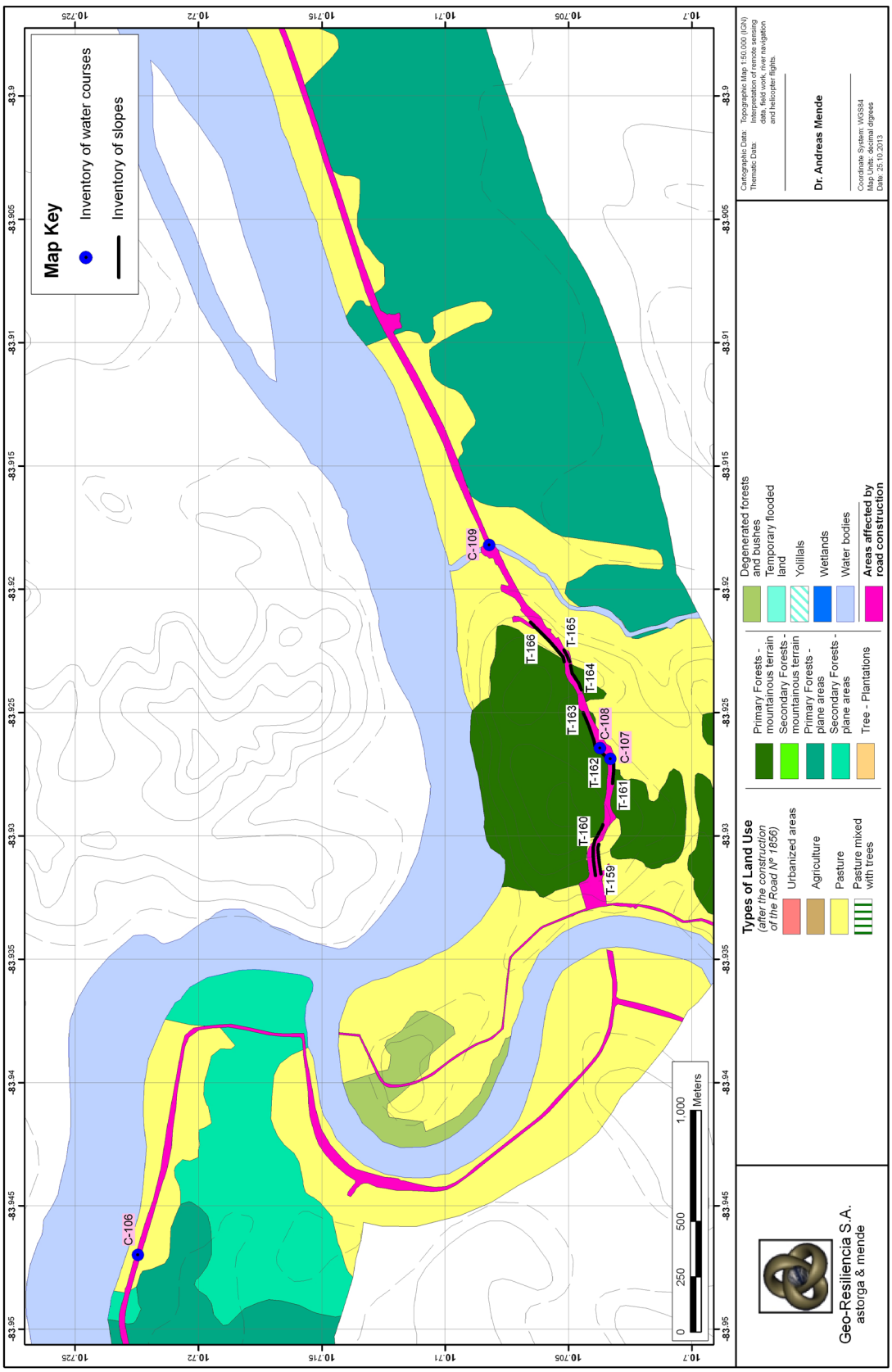

Map Key
Inventory of water courses
Inventory of slopes
0
250
500
1.000
Meters
C-76
C-77
C-78
C-79
C-80
C-81
C-82
C-83
C-84
C-85
T-105
T-106
T-107
T-108
T-109
T-110
T-111
T-112
T-113
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 25.10.2013
Geo-Resiliencia S.A.
astorga & mende

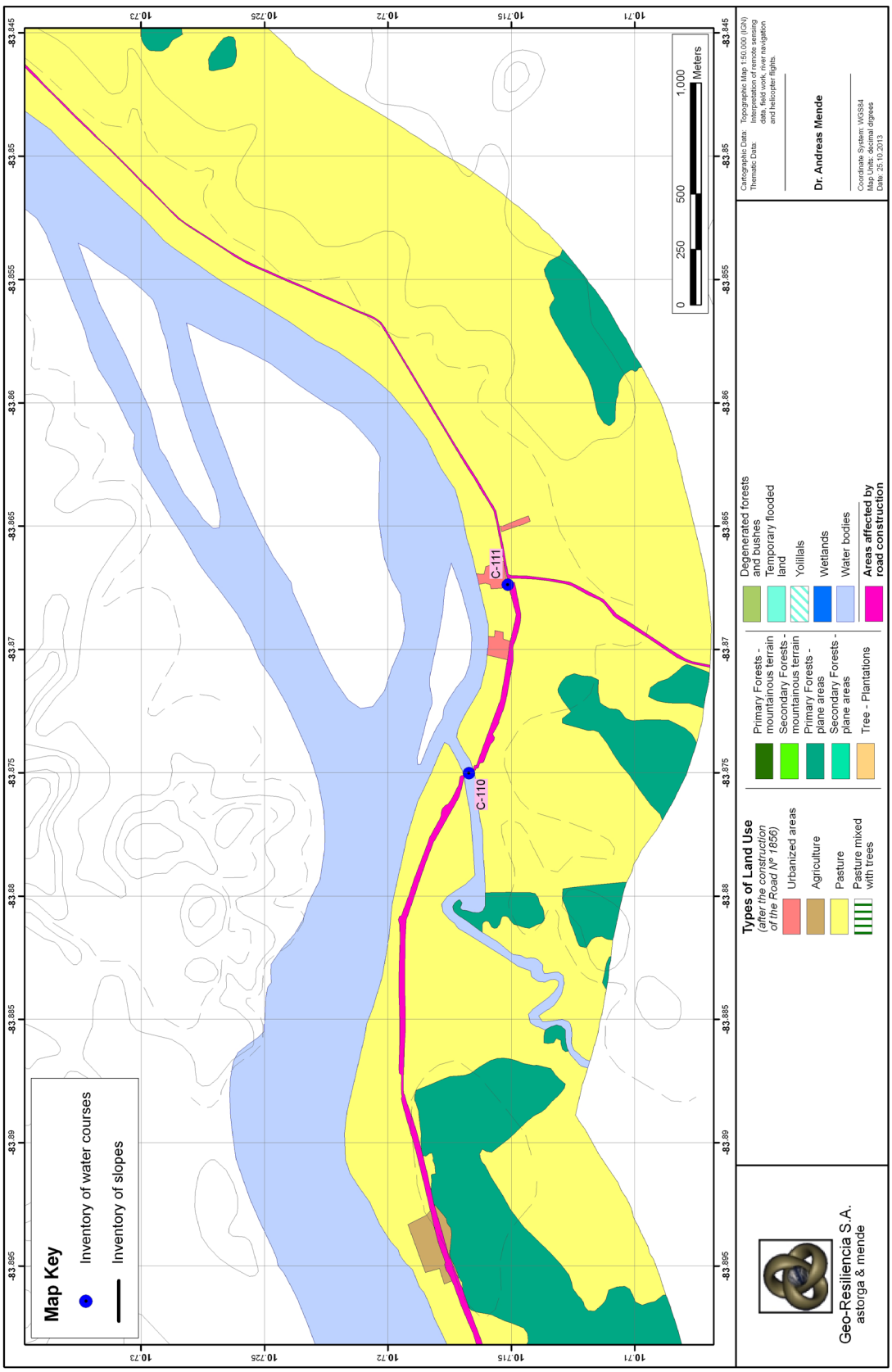

Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1,000 Meters
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 25.10.2013
Geo-Resiliencia S.A.
astorga & mende
C-86
C-87
C-88
C-89
T-114
T-115
T-116
T-117
T-118
T-119
T-120
T-121
T-122
T-123
T-124
T-125
T-126
T-127
T-128
T-129
T-130
T-131
T-132
T-133
T-134
T-135
T-136
T-137
T-138
10.775
10.77
10.765
10.76
10.755
-84.055
-84.06
-84.065
-84.07
-84.075
-84.08
-84.085
-84.09
-84.095
-84.1
-84.105

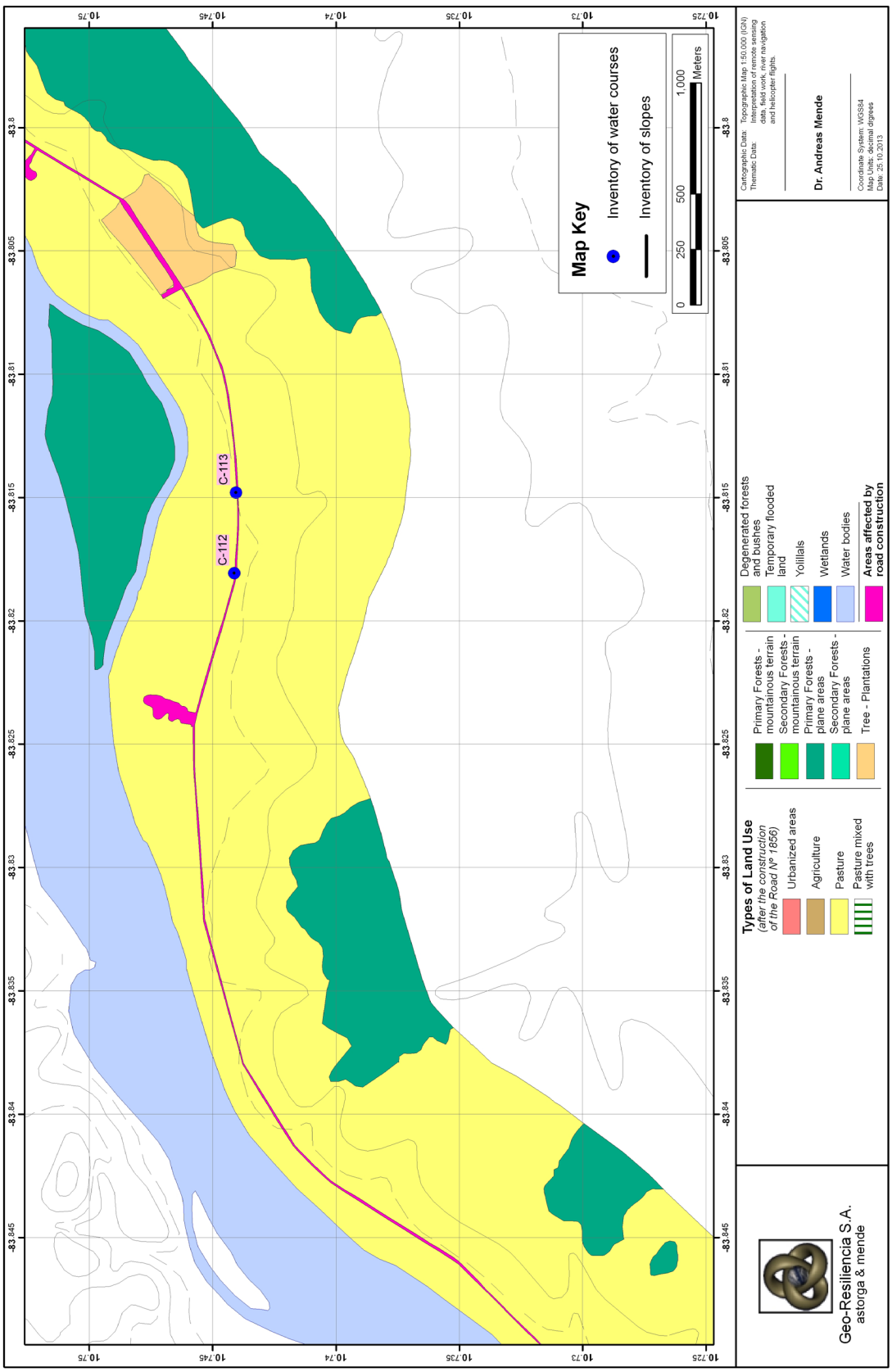

Map Key
Inventory of water courses
Inventory of slopes
0
250
500
1,000
Meters
C-102
C-103
C-104
C-101
C-91
C-92
C-92a
C-92b
C-94
C-95
C-91b
T-139
T-140
T-141
T-142
T-143
T-144a
T-144b
T-145a
T-145b
T-146
T-147a
T-147b
T-148
T-149
T-150
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 25.10.2013
Geo-Resiliencia S.A.
astorga & mende

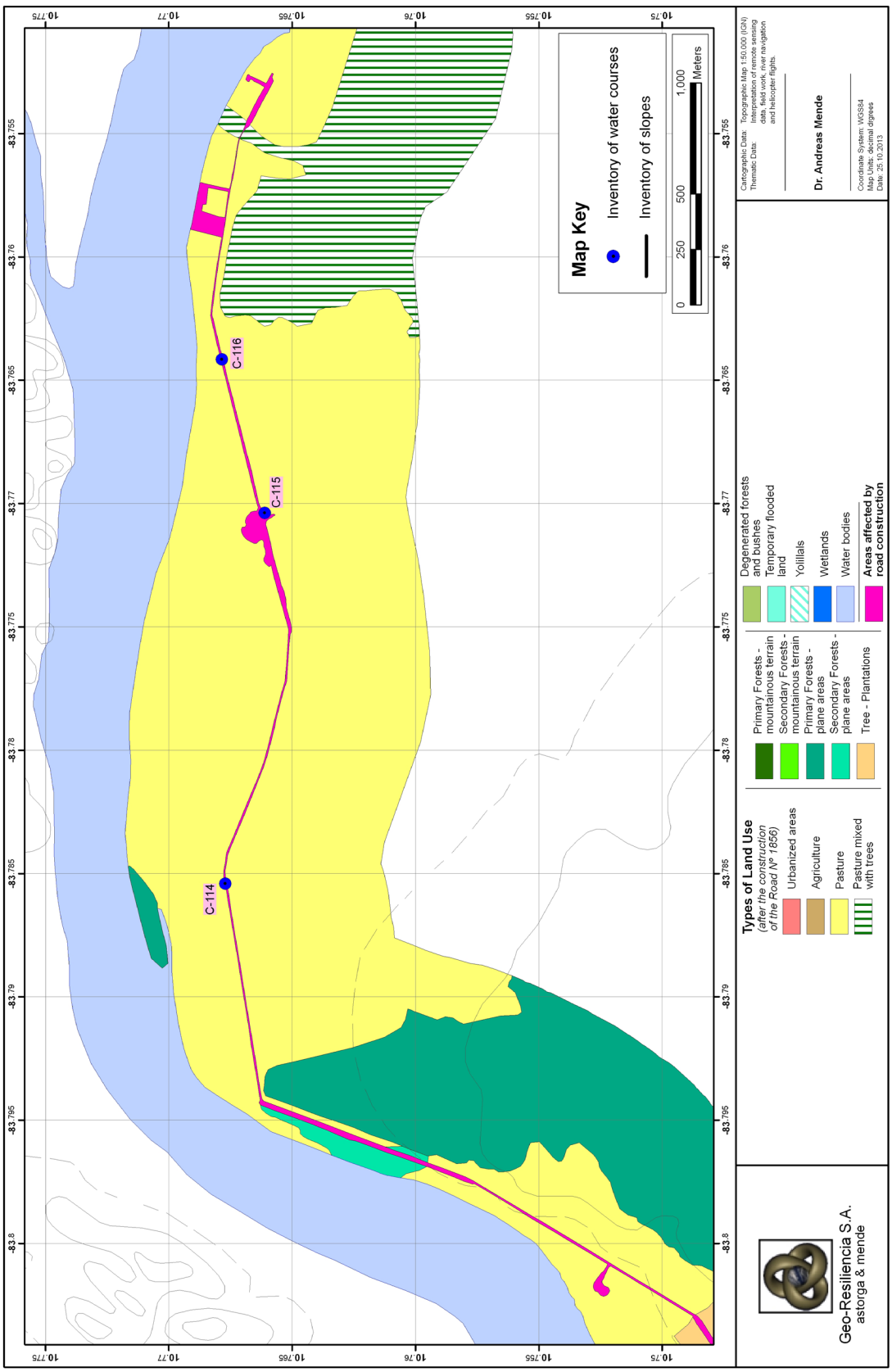

Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1,000
Meters
-84.01
-84.005
-84
-83.995
-83.99
-83.985
-83.98
10.785
10.78
10.775
10.77
10.765
10.76
10.755
10.75
10.745
10.74
T-151
T-152
T-153
T-154
C-96
T-155
T-156
T-157a
T-157b
C-97
C-98
C-99
T-158
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 25.10.2013


Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1,000
Meters
-83.975
-83.97
-83.965
-83.96
-83.955
-83.95
10.755
10.75
10.745
10.74
10.735
10.73
10.725
10.72
10.715
C-100
C-105
C-106
Geo-Resiliencia S.A.
astorga & mende
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal drgrees
Date: 25.10.2013


Map Key
Inventory of water courses
Inventory of slopes
C-106
C-109
T-166
T-165
T-164
T-163
C-108
C-107
T-162
T-161
T-160
T-159
0 250 500 1,000 Meters
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 23.10.2013


Map Key
Inventory of water courses
Inventory of slopes
C-110
C-111
0 250 500 1.000 Meters
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 23.10.2013
Geo-Resiliencia S.A.
astorga & mende


Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1.000 Meters
C-113
C-112
-83.845
-83.84
-83.835
-83.83
-83.825
-83.82
-83.815
-83.81
-83.805
-83.8
10.75
10.745
10.74
10.735
10.73
10.725
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 23.10.2013


Map Key
Inventory of water courses
Inventory of slopes
0 250 500 1,000 Meters
C-114
C-115
C-116
Types of Land Use
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Wetlands
Water bodies
Areas affected by road construction
Geo-Resiliencia S.A.
astorga & mende
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Coordinate System: WGS84
Map Units: decimal degrees
Date: 23.10.2013

6 PRESENT CONDITION OF SLOPES AND WATERCOURSE INTERSECTIONS

In this section we use statistical treatment of the base data to provide an overview of the present condition of watercourse intersections and slopes along Route 1856.

6.1 WATERCOURSE INTERSECTIONS

According to the inventory, there are 121 watercourse intersections along the Road between the Mojón II and Delta Costa Rica, including those at San Carlos and Sarapiquí Rivers, which are exceptionally large and which are, therefore, excluded from further statistical treatment.

Type Of Structure	Water courses (number)	Water courses (%)
Closed Land Fill	**16**	**13.4 %**
Land Fill with Drainage Tube	**48**	**40.3 %**
Land Fill with Bridge	**35**	**29.4 %**
Land Fill with Tree-Trunks	**3**	**2.5 %**
Bridge without Land Fill	**1**	**0.8 %**
Without any Construction	**16**	**13.4 %**
Sum	***119***	***100.0%***

Table 3: Statistical data regarding the type of structures used for crossing of water courses in the case of the border road.

The structural conditions of the watercourse intersections are summarized in Table 3. The results show that 84% of watercourses (excluding the San Carlos and Sarapiquí) are crossed by means of a variety of generally acceptable structures including 48 *Land Fills with Drainage Tubes, 35 Land Fills with Bridges* and 1 *Bridge without Land Fill*. There are 16 watercourse intersections where construction of any type a crossing has not yet commenced (see). At 16% of watercourse intersections, different technical solutions have been invoked, including 16 that have been closed by land fills and 3 where tree-trunks (rather than culverts have been installed to allow water to pass beneath the Road.

The present operational conditions of the crossings are summarized in Table 4. For 26 watercourses (22%), the present state is entirely acceptable This includes watercourses where there is an appropriate crossing solution or no impact due to construction of the

Road. At another 26 crossings (22%), technical improvements have been made and, although further corrective works may be necessary in future, the crossings will continue to be in an acceptable condition in the medium-term.

Present Technical State	Water courses (number)	Water courses (%)
Closed	**16**	**13.4 %**
Provisional	**42**	**35.3 %**
Improved	**26**	**21.8 %**
Appropriate	**10**	**8.4 %**
Broken	**9**	**7.6 %**
Without any Construction	**16**	**13.4 %**
Sum	***119***	***100.0%***

Table 4: Statistical data regarding the present technical state of structures used for crossing of water courses in the case of the border road.

42 crossings (35%) are currently in a provisional state and technical improvements are recommended within the near future. This recommendation also applies to the 16 (13%) of crossings that are closed and the 9 (8%) where the crossing structure is broken. Technical improvements are not time critical at these crossings, but should be undertaken once civil engineers have reviewed the watercourses and designed appropriate permanent crossing solutions.

In conclusion, conditions at crossings along Route 1856 can at present be described as typical during a construction period. Technical improvements have been made at some crossings, and these will be extended to other crossings that are in a provisional condition so that all crossings reach an acceptable condition in the future.

6.2 SLOPES

According to the inventory, there are 188 slopes (139 cut slopes 49 fill slopes) along Route 1856 between Mojón II and Delta Costa Rica (for more detailed data see Appendix A). Based on the slope inventory (as described in section 3, above), the overall length of these slopes is about 25.1 km and the total area of the slopes is estimated as 124,350 m^2.

According to the field surveys, the area presently affected by Sheet Erosion is around *63,200* m^2, which represents approximately 51% of the total area of the slopes (compare

Table 5). Extensive areas of Rills (26,250 m^2 or ~21%) and Gullies (20,160 m^2 or ~16%) were also inventoried. Landslides were observed to occupy 12,640 m^2 (~10%) of the total area. Mostly as a result of the re-established dense vegetation, 2,100 m^2 (2%) of observed slopes do not show identifiable erosion processes.

Types of Erosion	Slopes (Area m^2)	Slopes (Area %)
None	**2.100 m^2**	**2 %**
Sheet Erosion	***63.200* m^2**	**51 %**
Rills	***26.250* m^2**	**21 %**
Gullies	***20.160* m^2**	**16 %**
Land Slides	***12.640* m^2**	**10 %**
Sum	***124.350 m^2***	***100.0%***

Table 5: Statistical data regarding the types of erosion present at the slopes identified along the border road between Mojón II and Delta Costa Rica.

Mitigation Measures	Slopes (number)	Slopes (%)
Mitigation Measures (in general)	53	28.2 %
Geotextiles	10	5.3 %
Drainage Control	***18***	9.6 %
Stabilization by Terraces	***9***	4.8 %
Sowed Vegetation	***14***	7.4 %
Natural Vegetation	***20***	10.6 %
Sediment Tramps	14	7.4 %
Sum	***188***	

Table 6: Statistical data regarding the mitigation measures so fare done on the slopes along the border road between Mojón II and Delta Costa Rica.

As listed in Table 6, mitigation measures have so far been undertaken on 53 (28%) of the slopes, with a focus on drainage control (18 slopes, ~10%) and re-establishment of natural vegetation (20 slopes, ~11%). Sowed vegetation (principally different kinds of grass) as well as sediment traps had been deployed at 14 slopes (~7%) to reduce the sediment yield from the slope. Also, geotextiles (10 slopes, ~5%) and terracing (9 slopes, ~5%) have been used to stabilize slopes, mostly situated within the Segment 1 (between Mojón II and the Infiernito River).

As is the case with watercourse intersections, the present condition of the slopes along the border road between Mojón II and Delta Costa Rica can be considered to be typical of a road under construction. Mitigation measures have been undertaken to stabilize some of

the slopes and these works should be continued to control the runoff and reduce sediment yields along Route 1856.

7 ESTIMATION OF SEDIMENT YIELDS DUE TO EROSION AT SLOPES ALONG ROUTE 1856 BETWEEN MOJÓN II AND DELTA COSTA RICA

The UCR (2013) report presents the results of field monitoring of erosion and land surface lowering on cut and fill slopes encompassing the effects of sheet erosion, rills, gullies and landslides. The main findings of the report are summarized in Table 7. Nevertheless some clarifications are necessary. The erosion per year used for landslides are based on the results from the UCR (2013) report obtained for cut slopes because they were unable to record landslides in fill slopes (appropriate fill slopes were absent in their study area). The highest figure of 1.48 m/year was assigned to fill slopes because these are more unstable than cut slopes. The second clarification involves the 0.24 m/year figure used for sheet and rill erosion in fill slopes. The 0.24 m/year figure is based on the 0.20 m/year average erosion rate calculated for gully erosion in fill slopes by the UCR (2013) report, with an added 20% as a margin of safety in the approximation. As explained in detail in the UCR (2013) report, the 0.20 m/year rate is obtained by distributing the effects of gully erosion (which is triggered by overland flow) over the area of the fill slope in which they were found. It is considered that this can approximate the effects of sheet and rill erosion because these are both distributed processes triggered by flowing water.

Based on this data we calculated the total sediment yield from all the slopes included in the inventory of slopes along Route 1856 (for details see Appendix A). The first step was to identify the area occupied by each of the different erosion types (sheet erosion, rills, gullies and landslides), using the percentages observed in the field and listed in the database. The sediment yield for each slope was then found by multiplying the resulting surface areas the appropriate erosion depth, as listed in Table 7, and summing the yields for all the types of erosion present on that slope. The resulting estimates of average annual sediment yield may be found in *Appendix A*.

Erosive feature		Erosion of 1 m^2 per Year (m)
CUT SLOPES	*Sheet Erosion*	0.095
	Rills	0.17
	Gullies	0.21
	Landslides	0.5
FILL SLOPES	*Sheet Erosion*	0.24
	Rills	0.24
	Gullies	0.75
	Landslides	1.48

Table 7: Average erosion rate per square meter for the different types of slopes and erosive features based upon the study from Oreamuno & Villalobos (2013).

The total average annual sediment production for all the slopes along the Route 1856 between Mojón II and Delta Costa Rica is the sum of the sediment production of all 188 slopes which is around **36 590 m^3 y^{-1}** or **61 100 t y^{-1}** using the transform ratio 1:1.67 from the ICE Report (2013).

It is important to mention that this value should be regarded as a 'worst case' scenario because it is based on the highest values monitored for sediment yield from slopes in segment 1, which has a high number of slopes and the steepest gradients. Also, the effects of mitigation measures already installed on 53 of the slopes, which will reduce actual yields, are not taken into account in these calculations.

The average annual yield of sediment from slopes along the Road was reported to Dr. Federico Gomez-Delgado and his colleagues at ICE, who used these data in their assessment of sediment input from Route 1856 to the San Juan River.

8 REFERENCES

Astorga, A. & Mende, A. (2013): *Route 1856: Analysis of the Change in Land Use.*- Technical Report to the Ministry of Foreign Affairs. San José, Costa Rica.

Gomez-Delgado, F., Leitón-Montero, J.J. & Aguilar-Cabrera, C.A. (2013). *Report on hydrology and sediments for the Costa Rican river basins draining to the San Juan River*. San José, Costa Rica: Instituto Costarricense de Electricidad.

Oreamuno, R. & Villalobos, R. (2013): *Systematic Field monitoring of Erosion and Sediment Yield along Route 1856*.- Universidad de Costa Rica. San José, Costa Rica.

Appendix A: Overview about the most important data collected for Cut and Fill Slopes along the 1856 Road between Mojón II and Delta Costa Rica

Slope	Length (m)	Type	Height (m)	Area (m^2)	Gullies (area m^2)	Gullies (area %)	Rills (area m^2)	Rills (area %)	Landslides (area m^2)	Landslides (area %)	Sheet (area m^2)	Sheet (Area %)	Total Sediment / Year (m^3)
T-1	181.9	Cut	2.5	455	0	0	0	0	0	0	455	100	43
T-10	71.0	Cut	3.0	213	0	0	43	20	0	0	170	80	23
T-100	145.2	Cut	3.5	508	0	0	0	0	0	0	508	100	48
T-101	199.5	Cut	4.0	798	0	0	120	15	0	0	678	85	85
T-102a	31.8	Cut	1.5	48	0	0	0	0	0	0	10	20	1
T-102b	34.7	Fill	2.5	87	0	0	0	0	30	35	56	65	58
T-103	72.4	Cut	4.0	290	0	0	0	0	0	0	290	100	28
T-104	101.0	Cut	9.0	909	0	0	0	0	0	0	909	100	86
T-105	158.4	Cut	2.5	396	20	5	79	20	0	0	297	75	46
T-106	155.0	Cut	2.5	387	0	0	0	0	0	0	387	100	37
T-107	75.7	Fill	11.0	833	0	0	167	20	0	0	666	80	200
T-108	80.3	Cut	1.5	120	0	0	0	0	0	0	120	100	11
T-109	218.9	Fill	12.0	2627	1970	75	394	15	0	0	263	10	1635
T-11	86.2	Cut	2.0	172	0	0	0	0	0	0	34	20	3
T-110	162.5	Cut	3.5	569	0	0	0	0	0	0	569	100	54
T-111	68.4	Cut	4.0	274	0	0	0	0	82	30	192	70	59
T-112	69.0	Cut	3.5	241	0	0	0	0	0	0	241	100	23
T-113	73.8	Cut	1.2	89	0	0	0	0	0	0	89	100	8
T-114	202.3	Cut	8.0	1618	566	35	324	20	0	0	728	45	243
T-115	67.9	Cut	3.5	238	0	0	0	0	0	0	238	100	23
T-116	362.6	Fill	10.0	3626	1088	30	906	25	363	10	1269	35	1874
T-117	62.8	Fill	5.0	314	31	10	94	30	0	0	188	60	91
T-118	147.5	Cut	5.0	737	0	0	184	25	0	0	553	75	84
T-119	60.0	Cut	2.5	150	0	0	22	15	0	0	127	85	16
T-12	75.1	Cut	2.0	150	0	0	0	0	30	20	120	80	26
T-120	51.6	Cut	2.5	129	0	0	0	0	0	0	129	100	12
T-121	109.4	Fill	8.0	875	700	80	88	10	88	10	0	0	676
T-122	85.6	Cut	1.5	128	0	0	0	0	0	0	128	100	12
T-123	66.0	Fill	10.0	660	462	70	66	10	132	20	0	0	557
T-124	76.5	Cut	2.5	191	0	0	0	0	0	0	191	100	18
T-125	208.8	Cut	2.0	418	0	0	0	0	0	0	418	100	40
T-126	79.4	Fill	4.0	317	0	0	63	20	0	0	254	80	76
T-127	66.1	Cut	3.0	198	0	0	0	0	0	0	198	100	19
T-128	100.2	Cut	5.0	501	0	0	100	20	0	0	401	80	55
T-129	149.8	Fill	3.0	450	112	25	112	25	0	0	225	50	165
T-13	131.1	Cut	3.5	459	0	0	92	20	0	0	275	60	42
T-130	86.8	Cut	2.0	174	0	0	0	0	0	0	174	100	16
T-131	82.5	Cut	1.5	124	0	0	0	0	0	0	124	100	12
T-132	107.1	Fill	9.0	964	386	40	193	20	145	15	241	25	607
T-133	125.1	Cut	3.0	375	0	0	75	20	0	0	300	80	41
T-134	73.9	Fill	3.0	222	111	50	66	30	0	0	44	20	110
T-135	109.1	Fill	4.0	437	44	10	175	40	0	0	218	50	127
T-136	129.8	Cut	2.0	260	0	0	52	20	78	30	130	50	60
T-137	65.1	Cut	2.5	163	0	0	0	0	41	25	122	75	32
T-138	72.8	Cut	1.0	73	0	0	0	0	0	0	73	100	7
T-139	124.3	Cut	4.0	497	50	10	199	40	0	0	249	50	68
T-14	203.7	Cut	3.0	611	122	20	244	40	183	30	61	10	165
T-140	75.0	Cut	2.0	150	0	0	0	0	38	25	113	75	29
T-141	198.6	Cut	1.5	298	0	0	0	0	0	0	298	100	28
T-142	93.5	Fill	1.8	168	0	0	34	20	0	0	135	80	40
T-143	85.8	Cut	1.5	129	0	0	0	0	0	0	129	100	12
T-144a	78.1	Fill	1.5	117	0	0	18	15	0	0	100	85	28

Slope	Length (m)	Type	Height (m)	Area (m^2)	Gullies (area m^2)	Gullies (area %)	Rills (area m^2)	Rills (area %)	Landslides (area m^2)	Landslides (area %)	Sheet (area m^2)	Sheet (Area %)	Total Sediment / Year (m^3)
T-144b	77.2	Fill	1.5	116	0	0	17	15	0	0	98	85	28
T-145a	65.5	Cut	1.5	98	0	0	0	0	0	0	98	100	9
T-145b	55.4	Cut	1.5	83	0	0	0	0	0	0	83	100	8
T-146	68.2	Cut	3.0	205	0	0	0	0	0	0	205	100	19
T-147a	91.1	Cut	1.5	137	0	0	0	0	0	0	137	100	13
T-147b	95.2	Cut	1.5	143	0	0	0	0	0	0	143	100	14
T-148	70.0	Cut	3.5	245	0	0	0	0	0	0	245	100	23
T-149	113.1	Cut	4.0	453	0	0	0	0	0	0	453	100	43
T-15	213.0	Cut	3.5	745	0	0	373	50	0	0	224	30	85
T-150	54.3	Cut	2.5	136	0	0	27	20	0	0	109	80	15
T-151	16.8	Cut	2.5	42	0	0	0	0	0	0	42	100	4
T-152	33.1	Fill	2.0	66	17	25	17	25	0	0	33	50	24
T-153	133.3	Cut	4.0	533	0	0	0	0	0	0	533	100	51
T-154	95.6	Cut	2.5	239	0	0	0	0	0	0	239	100	23
T-155	47.2	Fill	2.0	94	28	30	19	20	0	0	47	50	37
T-156	82.7	Cut	3.5	290	0	0	58	20	0	0	232	80	32
T-157a	109.6	Fill	1.5	164	25	15	49	30	0	0	90	55	52
T-157b	110.1	Fill	1.5	165	0	0	41	25	0	0	124	75	40
T-158	325.1	Cut	4.0	1300	130	10	390	30	0	0	780	60	168
T-159	133.4	Cut	2.0	267	0	0	107	40	0	0	160	60	33
T-16	119.3	Cut	3.5	418	0	0	0	0	0	0	418	100	40
T-160	237.4	Cut	2.0	475	0	0	0	0	190	40	285	60	122
T-161	90.3	Cut	2.5	226	0	0	0	0	0	0	226	100	21
T-162	45.1	Fill	2.0	90	0	0	0	0	45	50	45	50	78
T-163	157.9	Cut	1.5	237	0	0	0	0	0	0	237	100	23
T-164	121.8	Cut	4.0	487	0	0	0	0	0	0	487	100	46
T-165	58.3	Fill	3.0	175	0	0	52	30	0	0	122	70	42
T-166	234.9	Cut	2.5	587	0	0	0	0	0	0	587	100	56
T-17	191.4	Cut	3.0	574	0	0	0	0	115	20	459	80	214
T-19	147.9	Cut	6.0	887	0	0	266	30	0	0	621	70	104
T-2	69.7	Cut	2.0	139	0	0	0	0	0	0	139	100	13
T-20	86.0	Cut	4.0	344	0	0	0	0	0	0	69	20	7
T-21a	382.1	Cut	6.0	2293	0	0	0	0	802	35	1490	65	543
T-21b	387.0	Cut	3.0	1161	0	0	0	0	0	0	1161	100	110
T-22	362.8	Cut	4.0	1451	0	0	290	20	0	0	798	55	125
T-23	63.0	Cut	3.0	189	0	0	0	0	0	0	57	30	5
T-24a	94.5	Cut	1.7	161	0	0	0	0	16	10	80	50	16
T-24b	103.5	Cut	1.7	176	0	0	0	0	18	10	88	50	17
T-25	52.1	Cut	1.5	78	0	0	0	0	0	0	8	10	1
T-26	40.7	Cut	1.5	61	0	0	0	0	0	0	6	10	1
T-27	174.9	Cut	2.0	350	0	0	0	0	35	10	210	60	37
T-28	96.4	Cut	3.0	289	0	0	0	0	101	35	116	40	62
T-29	188.5	Cut	4.0	754	0	0	0	0	113	15	302	40	85
T-3	36.8	Cut	1.5	55	0	0	0	0	0	0	55	100	5
T-30	122.9	Cut	4.0	491	0	0	0	0	0	0	491	100	47
T-31	146.2	Cut	1.5	219	0	0	0	0	0	0	219	100	21
T-32a	226.8	Cut	4.0	907	0	0	0	0	0	0	907	100	86
T-32b	221.7	Cut	20.0	4433	0	0	665	15	222	5	3547	80	561
T-33	194.3	Cut	4.0	777	0	0	117	15	155	20	505	65	298
T-34	54.6	Cut	3.0	164	0	0	0	0	0	0	164	100	16
T-35	128.1	Cut	3.0	384	0	0	0	0	77	20	308	80	68
T-36	29.5	Cut	1.2	35	0	0	0	0	0		35	100	3
T-37	202.6	Cut	5.0	1013	203	20	304	30	152	15	354	35	204
T-38	320.3	Cut	15.0	4805	1441	30	1441	30	1201	25	721	15	2394

Slope	Length (m)	Type	Height (m)	Area (m^2)	Gullies (area m^2)	Gullies (area %)	Rills (area m^2)	Rills (area %)	Landslides (area m^2)	Landslides (area %)	Sheet (area m^2)	Sheet (Area %)	Total Sediment / Year (m^3)
T-39	321.5	Cut	5.0	1608	0	0	322	20	0	0	1286	80	177
T-4	31.8	Cut	1.5	48	0	0	0	0	0	0	48	100	5
T-40	295.5	Cut	5.0	1478	0	0	296	20	369	25	961	65	326
T-41	135.6	Cut	8.0	1085	217	20	434	40	217	20	217	20	461
T-42	360.2	Cut	7.0	2522	504	20	1009	40	756	30	252	10	680
T-43	390.0	Fill	12.0	4680	936	20	1872	40	468	10	1404	30	2181
T-44	146.6	Cut	2.5	367	73	20	128	35	55	15	110	30	75
T-45a	45.8	Fill	6.0	275	0	0	110	40	0	0	165	60	66
T-45b	51.5	Fill	8.0	412	0	0	165	40	0	0	247	60	99
T-46	139.5	Cut	5.0	698	279	40	174	25	174	25	70	10	182
T-47	53.9	Cut	3.0	162	0	0	24	15	32	20	105	65	30
T-48	232.4	Cut	2.5	581	116	20	232	40	0	0	232	40	86
T-49	156.6	Cut	3.0	470	0	0	164	35	0	0	305	65	57
T-5	98.3	Cut	1.8	177	0	0	0	0	0	0	177	100	17
T-50	217.1	Cut	3.0	651	0	0	261	40	163	25	228	35	147
T-51	140.1	Cut	4.0	561	0	0	224	40	112	20	224	40	115
T-52	78.1	Fill	1.5	117	0	0	94	80	0	0	23	20	28
T-53	45.0	Fill	7.0	315	126	40	157	50	0	0	31	10	140
T-54	63.7	Cut	2.0	127	0	0	0	0	0	0	127	100	12
T-55	113.8	Cut	2.5	284	0	0	43	15	0	0	242	85	30
T-56	48.7	Fill	25.0	1219	244	20	305	25	427	35	244	20	946
T-57a	177.5	Fill	3.0	532	106	20	106	20	0	0	319	60	182
T-57b	219.8	Cut	2.5	550	137	25	192	35	0	0	220	40	82
T-58a	189.1	Fill	8.0	1513	0	00	454	30	0	0	1059	70	363
T-58b	184.8	Cut	6.0	1109	0	0	333	30	222	20	555	50	220
T-59	191.5	Cut	3.0	574	144	25	230	40	57	10	144	25	112
T-6	73.2	Cut	2.2	161	0	0	0	0	0	0	161	100	15
T-60	109.3	Fill	14.0	1530	612	40	306	20	612	40	0	0	1439
T-61	118.0	Cut	3.0	354	106	30	142	40	0	0	106	30	56
T-62	100.9	Cut	1.5	151	0	0	76	50	0	0	76	50	20
T-64a	89.7	Cut	3.0	269	0	0	40	15	0	0	229	85	29
T-64b	88.1	Fill	25.0	2201	881	40	440	20	0	0	881	40	977
T-65a	94.2	Cut	9.0	848	0	0	85	10	127	15	636	75	138
T-65b	100.7	Fill	20.0	2014	1209	60	403	20	0	0	403	20	1100
T-66a	207.8	Cut	8.0	1662	499	30	249	15	499	30	416	25	436
T-66b	196.7	Fill	8.0	1574	472	30	472	30	0	0	630	40	619
T-67	98.7	Cut	7.0	691	0	0	104	15	104	15	483	70	115
T-68a	40.4	Fill	9.0	364	218	60	73	20	0	0	73	20	199
T-68b	35.8	Fill	12.0	430	301	70	86	20	0	0	43	10	257
T-69a	99.9	Cut	7.0	699	0	0	105	15	105	15	489	70	117
T-69b	94.3	Fill	15.0	1415	283	20	283	20	142	10	708	50	659
T-70a	48.8	Cut	7.0	341	0	0	51	15	51	15	239	70	57
T-70b	45.1	Fill	15.0	677	135	20	135	20	68	10	338	50	315
T-71	57.7	Cut	9.0	519	0	0	0	0	0	0	519	100	49
T-72a	66.4	Fill	9.0	597	358	60	119	20	0	0	119	20	326
T-72b	68.3	Fill	9.0	615	369	60	123	20	0	0	123	20	336
T-73a	223.0	Cut	8.0	1784	446	25	446	25	446	25	446	25	435
T-73b	216.6	Fill	15.0	3249	812	25	1137	35	325	10	975	30	1597
T-74a	63.4	Fill	6.0	380	133	35	95	25	152	40	0	0	348
T-74b	61.6	Fill	6.0	370	159	43	63	17	148	40	0	0	353
T-75	111.6	Cut	5.0	558	0	0	167	30	112	20	279	50	111
T-76a	155.1	Cut	2.0	310	0	0	62	20	0	0	248	80	34
T-76b	159.5	Fill	2.0	319	0	0	64	20	0	0	255	80	77
T-77	98.0	Fill	1.0	98	15	15	15	15	0	0	69	70	31

Slope	Length (m)	Type	Height (m)	Area (m^2)	Gullies (area m^2)	Gullies (area %)	Rills (area m^2)	Rills (area %)	Landslides (area m^2)	Landslides (area %)	Sheet (area m^2)	Sheet (Area %)	Total Sediment / Year (m^3)
T-78	176.7	Cut	2.5	442	0	0	0	0	44	10	397	90	60
T-79	38.2	Cut	5.0	191	0	0	0	0	0	0	191	100	18
T-7a	44.6	Fill	3.0	134	54	40	40	30	0	0	40	30	59
T-7b	52.0	Fill	3.0	156	62	40	47	30	0	0	47	30	69
T-80	121.4	Cut	3.0	364	0		0	0	0	0	364	100	35
T-81	238.5	Cut	16.0	3817	572	15	1336	35	0	0	1908	50	529
T-82a	171.6	Cut	6.0	1030	103	10	412	40	0	0	515	50	141
T-82b	170.6	Cut	4.0	682	68	10	273	40	0	0	341	50	93
T-83	999.8	Cut	3.0	2999	300	10	900	30	0	0	1800	60	387
T-84	100.6	Cut	4.0	402	0	0	0	0	80	20	322	80	71
T-85a	375.5	Cut	9.0	3379	507	15	507	15	676	20	1690	50	691
T-85b	384.6	Fill	10.0	3846	577	15	577	15	769	20	1923	50	2171
T-86	332.8	Cut	1.8	599	0	0	0	0	240	40	359	60	154
T-87	289.0	Cut	1.8	520	52	10	78	15	0	0	130	25	37
T-88	58.8	Cut	2.5	147	0	0	0	0	0	0	147	100	14
T-89	95.2	Cut	1.5	143	0	0	21	15	36	25	86	60	30
T-8a	163.0	Cut	3.0	489	98	20	147	30	196	40	49	10	148
T-8b	166.1	Fill	4.0	664	266	40	332	50	0	0	66	10	295
T-9	108.7	Cut	2.0	217	0	0	141	65	43	20	33	15	49
T-90	136.7	Cut	1.8	246	0	0	49	20	25	10	172	70	37
T-91	192.2	Cut	2.0	384	0	0	77	20	38	10	269	70	58
T-92	55.7	Cut	1.5	84	0	0	0	0	0	0	84	100	8
T-93	69.0	Cut	1.5	104	0	0	0	0	0	0	104	100	10
T-94a	147.5	Fill	3.0	443	0	0	133	30	0	0	310	70	106
T-94b	146.2	Cut	3.0	439	0	0	132	30	0	0	307	70	52
T-95	42.1	Fill	1.5	63	0	0	50	80	0	0	13	20	15
T-96	80.1	Cut	3.0	240	0	0	24	10	0	0	216	90	25
T-97	103.8	Cut	5.0	519	104	20	156	30	104	20	104	20	110
Sum	***25091.2***			***124381***	***20160***		***26245***		***12644***		***63203***		***36587***

ANNEX 7

Note from Ana Lorena Guevara Fernández, Vice-Minister of the Environment, Costa Rica, to En**r**ique Castillo Barrantes, Minister of Foreign Affairs, Costa Rica

Report on the progress in the Environmental Management Plan of Route Juan Rafael Mora Porras, executed by the Ministry of the Environment and Energy

Reference DVM-293-2013,

8 October 2013

English Translation

San José, 8 October 2013
DVM-293-2013

Enrique Castillo Barrantes
Minister of Foreign Affairs
Ministry of Foreign Affairs

Honourable Minister:

I am pleased to address you to send my greetings and to refer to the progress achieved in complying with that set forth in the Environmental Management Plan of Route Juan Rafael Mora Porras, executed by the Ministry of the Environment and Energy (Ministerio de Ambiente y Energía), within the framework of Executive Decree N°36440-MP and the General Emergency Plan, a situation and process triggered by Nicaragua's violation of Costa Rican sovereignty.

In conformity with Appendix N°3 of the aforementioned plan, I am detailing below the achievements thus far:

1) To minimize the possible effects of slopes caused by the construction of the road and its effect on water resources, we hired the company Corporación de Desarrollo Forestal de la Zona Norte (CODEFORSA), which is currently implementing a plan to recover the forest cover in areas with slopes of Route 1856. This project has addressed 12 slope areas in total, in which vetiver grass has been planted. In addition, the entity in charge of supervising the construction of Route 1856, CONAVI, has placed geoblankets in areas with pronounced cuts.

Since the beginning of 2012 a process was initiated to recover forest cover on the right bank of San Juan River, using native species such as “sotacaballo” (*Zygia longifolia*), used traditionally by the inhabitants to stabilize soil next to bodies of water. Other species planted include: Ceibo (*Vochysia guatemalensis*), almendro (*Dipteryx panamensis*), javillo (*Hura crepitans*), chilamate (*Ficus insípida*), among others. To date approximately 27,000 trees of native species have been planted, and these are between 1 and 3 metres high, depending on the species. At the end of September 2013 a second phase of the reforestation project began on the bank of San Juan River, and it is expected to include 25,000 more trees, to reach a total of 52,000 trees.

Group of volunteers receive technical instructions for tree planting

Demonstration of the planting method

Volunteers perform recovery of vegetation cover on the bank of San Juan River, on Costa Rican territory

Current state of plantations initiated in 2012. Some trees are over 2 m tall.

Volunteers during the planting process of the second phase of reforestation, initiated in September of this year.

The planted areas receive periodic maintenance consisting of mowing, application of fertilizer, pruning, fence maintenance, and labelling. All of this care is provided over the course of two years to guarantee that the trees continue growing on their own after that period.

Other actions indicated by the Environmental Management Plan include the construction of sediment traps, step drains and ditches. This activity has been managed by the Consejo Nacional de Vialidad (CONAVI), since it is in charge of the construction of the road.

Placement of silt fence in slope areas

Slopes covered with geoblanket to prevent runoff

Protective barriers to prevent runoff

Ditches created to channel runoff water

Placement of concrete pipes at small stream passages

Step drain to reduce the speed of rainwater

Finally, I report that this Ministry has implemented a Plan for Prevention, Control and Protection to improve surveillance in the area. The employees of the Sistema Nacional de Áreas de Conservación (SINAC) are responsible for the implementation of this plan, with the support of the Ministry of Public Safety (Ministerio de Seguridad Pública). Through monitoring and control activities it has been possible to: obtain an updated registry of the inhabitants in the region; detecting illegal activities such as illegal hunting, felling of forests and of forbidden types of timber, seizure of timber; and dismantling of new construction at natural heritage sites of the Government.

Similarly, the construction of 3 MINAE surveillance stations has begun, on three strategic points along Route 1856, for better control and protection of the Border Wildlife Corridor Refuge (Refugio de Vida Silvestre Corredor Fronterizo).

Regards,

Ana Lorena Guevara Fernández
Vice-Minister of the Environment

C Mr. René Castro Salazar, MINAE Minister

ANNEX 8

Consejo Nacional de Vialidad (CONAVI),

Program for the Consolidation and Continued Improvement of Route No 1856

Reference DIE-02-13-3107

25 October 2013

English Translation

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

25 October 2013

PROGRAM FOR THE CONSOLIDATION AND CONTINUED IMPROVEMENT OF ROUTE N° 856, JUAN RAFAEL MORA PORRAS

The Ministry of Public Works and Transport (Ministerio de Obras Públicas y Transportes, MOPT) and Consejo Nacional de Vialidad (CONAVI) continue the works for the consolidation of Route N° 856, Juan Rafael Mora Porras, and to give attention to certain points that require complementary works so as to mitigate the effects of the rain. All works seek to continue the consolidation of the route and, where circumstances require it, perform remediation works. All of these works constitute measures of compensation or environmental mitigation, with the goal of adequately managing the sediment that may be generated due to erosion and the adequate channelling of surface run-off.

During February, March and April the following works were performed:

- **General Information**

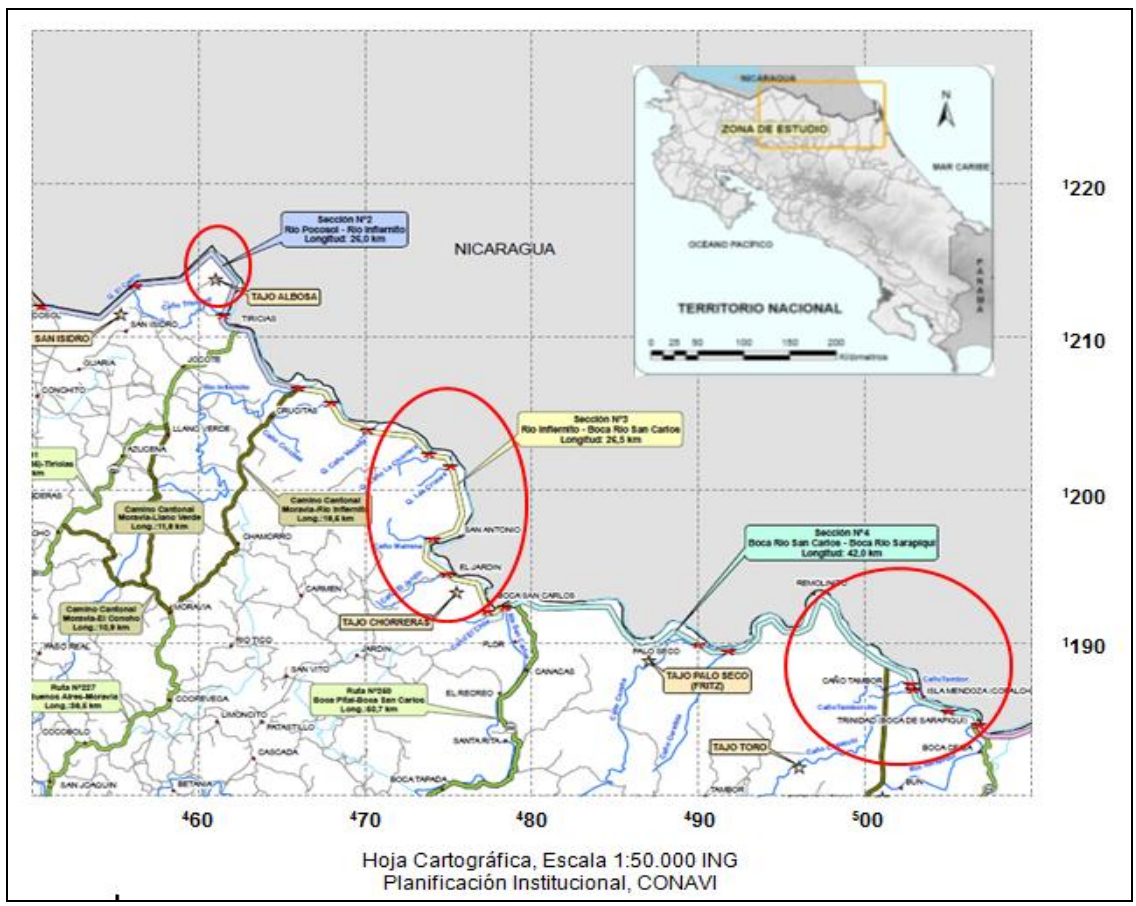
Region :	Huetar Norte
Province :	Alajuela
Type of Work :	Mitigation works
Construction Company :	MECO S.A.
Resident Engineer (Company):	Jonathan Granados Castillo, Eng.
Technical Director (Company):	Benjamín Meneses Monastel, Eng.
Project Engineer (CONAVI):	José Mena Carmona, Eng.
Length :	15 km
Abbreviated bidding:	2012LA-000072-0DI00
Contract signing date :	5-feb-2013
Date of Order to begin works :	11-feb-2013
Date of completion :	12-abril-2013
Project status :	Completed
Contract amount :	¢669.900.000,00
Original term of the construction works :	60 business days
Physical progress	100%
Financial progress	93.13%

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

- **Geographic location of the project**



The works were performed according to Abbreviated Bidding No. 2012LA-000072-0DIOO, located in sections 2, 3 and 4 (mountain and wetlands area) of Route 1856 (Juan Rafael Mora Porras), in provinces 02 and 04: Alajuela and Heredia; cantons 210 and 410: San Carlos and Sarapiquí; districts 13, 11 and 02: Cutris, Pocosol and La Virgen.

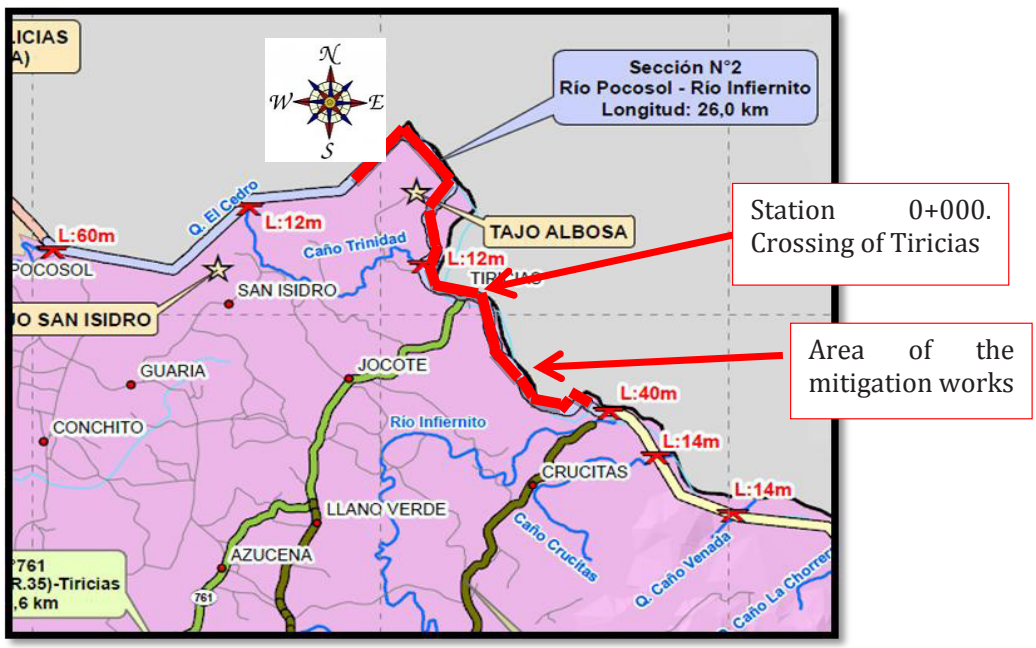
Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

- **Description of the works**

Work was carried out in the Tiricias sector, and the project spanned the approximate distance of 15 km. The figure below depicts this sector.



The stations for this project are as follows: from the crossing of Tiricias (Est. 0+000) to the Southeast the values are positive; and from the crossing of Tiricias to the Northwest the values are indicated preceded by a minus sign (-).

Works performed:

- Placement of sediment control barriers
- Placement of geoblanket for erosion control
- Excavation and filling of slopes on embankments
- Placement of culverts with a 90 cm diameter, with the corresponding headwalls
- Construction of reinforced concrete top ditches, class X, 10 cm thick
- Excavation of channels and construction of sediment traps

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

- Construction of concrete energy dissipators, 15m long

The following table shows the amounts invested in carrying out the mitigation works, which were performed with CONAVI budget.

	ITEM	UNIT	COST
1	Placement of sediment control barriers (Siltfence barrier)	m	13.447.244,98
2	Placement of geo blanket for erosion control (Coconut fibre blanket)	m2	93.836.827,17
3	Excavation and filling of slopes on embankments (Common excavation)	m3	115.767.909,03
4	Excavation and filling of slopes on embankments (Embankment construction)	m3	124.566.092,44
5	Placement of culverts with a 90cm diameter, with the corresponding headwalls (Reinforced concrete pipe, Class III C-76, 0,90m diameter)	m	29.892.432,32
6	Construction of reinforced concrete top ditches, Class X 10cm thick	m2	21.559.648,78
7	Excavation of channels and construction of sediment traps	m3	4.888.838,64
9	Structural reinforced concrete, Class X, 180kg/cm2: for dissipators and headings	m3	38.281.898,46
8	Construction of concrete energy dissipators, 15m long		13.628.284,50
9	Item 110,06		13.628.284,50
10	Construction of concrete dissipators, Class X	m2	202.505.265,33
		TOTAL	**672.002.726,15**

The discrepancy between the total in the table above and the amount approved under the contract is due to adjustments made in the process of settling the contract, and once the process was underway.

- **Pictures of the project:**

Picture 1. Creation of slopes, placement of coconut fibre, construction of ditches and placement of siltfence

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Picture 2. Creation of slopes, placement of coconut fibre, construction of ditches and placement of silt fence

Picture 3. Creation of slopes, placement of coconut fibre, building of top ditches

Picture 4. Construction of dissipators

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Picture 5. Creation of slopes, construction of ditches and top ditches

Picture 6. Placement of pipes, construction of headwalls, construction of ditches

Picture 7. Placement of coconut fibre, construction of ditches

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Picture 8. Construction of lined channels, placement of coconut fibre, building of ditches

Picture 9. Placement of coconut fibre, building of ditches

Picture 10. Creation of slopes, placement of coconut fibre, construction of ditches, placement of ballast and placement of silt fence

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Picture 11. Creation of slopes, placement of coconut fibre, building of ditches and placement of siltfence

Picture 12. Placement of coconut fibre, construction of ditches, placement of silt fence

Please find below the comparative tables reflecting the situation before and after the work performed, with the corresponding geographic location.

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 1

Stations (-) 7+760 (-) 7+400 (-) 7+350
Lambert GPS Coordinates N 329945, E 496508
Description: Direction toward Marker II, Right side: creation of banks and placement of geoblanket. Excavation and lining for transversal channels with surface depth wetland water and concrete pipes

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 2

Stations (-) 7+250 (-) 7+200
Lambert GPS Coordinates N 330352 E 496887
Description: Direction toward Marker II. Right side: creation of banks and placement of geoblanket. Excavation for transversal channels with surface depth wetland water and lined ditch.

BEFORE	AFTER

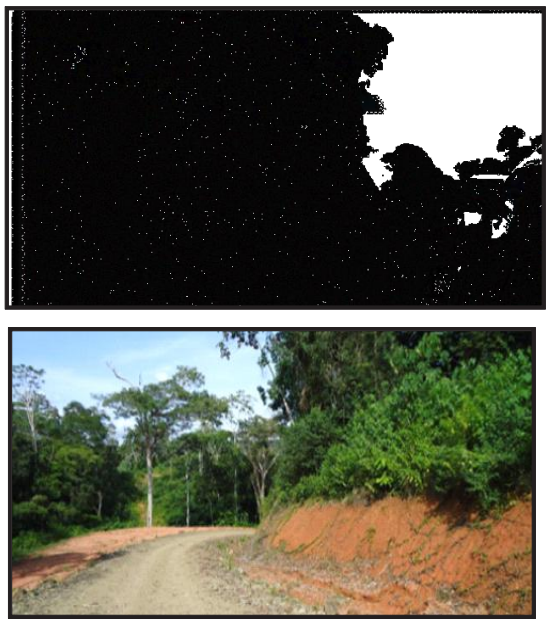
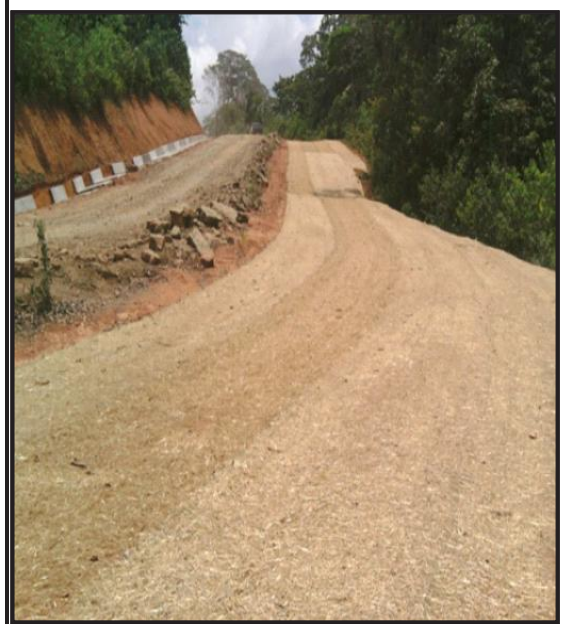
Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 3

Stations (-) 7+140
Lambert GPS Coordinates N 330329 E 496942
Description: Left side, Right side - creation of slopes and placement of geoblanket
Left side - excavation of ditches, construction of lined ditch

BEFORE	AFTER
	

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 4

Stations (-) 6+750
Lambert GPS Coordinates N 330052 E 497114
Description: Left side, Right side, creation of slopes and placement of geoblanket.
Left side, Right side, excavation for ditches, construction of lined ditch, 2 drainpipes with dissipators

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 5

Stations (-) 6+350
Lambert GPS Coordinates N 329855 E 497430
Description: Left side, construction of bank, placement of geoblanket and lined ditch
Right side; refine slope, place geoblanket and lined ditch

BEFORE	AFTER

Point 6

Stations (-) 4+576
Lambert GPS Coordinates N 328515 E 498489
Description: Left side, fill slope

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 7

Stations (-) 0+622
Lambert GPS Coordinates N 325345 E 498072
Description: Right side, over 80 m: define slope, place geoblanket, construction of headwalls on existing passage, line channel exit

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 8

Stations (-) 0+300
Description: Drain passage, 90cm diameter, with surface depth wetland water, headings, and line channel exit

BEFORE	AFTER

Point 9

Stations 0+480
Lambert GPS Coordinates N 325177 E 499060
Description: Right side, construction of a step drain and lining of the exit channel

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 10

Stations 0+550 to 0+804
Lambert GPS Coordinates N 325163 E 499126
Description: Right Side, Construction of drainage channel

BEFORE	AFTER

Point 11

Stations 1+109
Lambert GPS Coordinates N 324868 E 499477
Description: Ditch passage and headwalls, 1.5 m diameter

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 12

Stations 1+030 1+090
Description: Left side, digging of channel

BEFORE	AFTER

Point 13

Stations 1+195 - 1+365 - 1+407
Lambert GPS Coordinates N 324757 E 499503
Description: Left side, slope of 250x20m, 250m of top ditches, 500m of siltfence, 80m of dissipator (4 for top ditches), Left side embankment, construction of lined ditch, digging of ditch, Right side lined ditch

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 14

Stations 2+600 - 2+657 - 2+755 - 2+890
Description: Right side, Improve bank, lined ditch, remove landslides and cut into terraces

BEFORE	AFTER

Point 15

Stations 2+960
Description: Right Side, create slope, material for use in other activities

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 16

Stations 3+604
Description: Right side, create slope, material for use in other activities

BEFORE	AFTER

Point 17

Stations 3+690 3+720 3+830 4+000
Description: Left side. Dissipators, top ditches, ditches, protection with silt fence
Left side, construction of lined ditch and dissipator
Right Side construction of lined ditch and dissipator, digging to fill bank with cut material
Left side, embankment and filling
Right side, Landslide

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 18
Stations 4+185
Lambert GPS Coordinates N 322071 E 500667
Description: Ditch, top ditch, coconut fibre geoblanket. Creation of slope, left and right sides.
Right side, cut slope and fill bank

BEFORE	AFTER

Point 19
Stations 4+330
Lambert GPS Coordinates N 321987 E 500774
Description: Drain passage
Excavation for pipes
Filling for pipes
Pipes with an internal diameter of 1.5 metres
Heading for tube with a diameter of 1.5 metres
Class A concrete for skirtboard

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 20
Stations 6+704 - 7+000
Description: Digging of loose material
Creation of slopes
Coconut fibre geoblanket for erosion control
Sediment barrier

BEFORE	AFTER

Point 21

Stations 7+050
Lambert GPS Coordinates N 321779 E 500975
Description: Digging of loose material
Creation of slopes
Coconut fibre geoblanket for erosion control
Sediment barrier

BEFORE	AFTER

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point 22
Stations 7+350 - 7+750
Description: Digging of loose material
Creation of slopes
Coconut fibre geoblanket for erosion control
Sediment barrier

BEFORE	AFTER

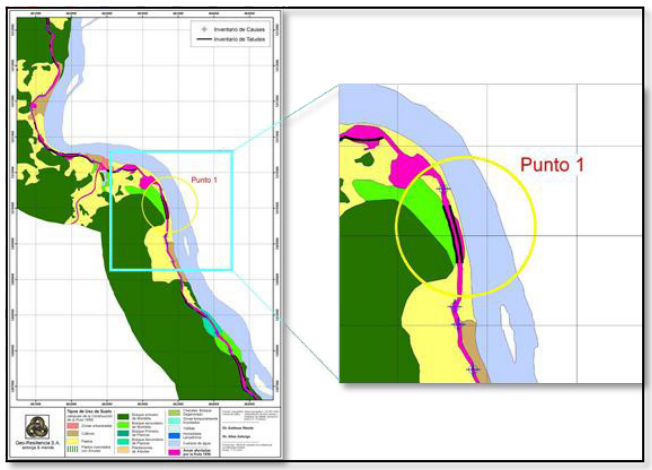
Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Works currently being carried out include the cleaning and conservation of works built last year and during February, March and April. New sectors of the route will be covered, but with specific emphasis of the sectors identified in Section N° 2; Río Pocosol – Río Infiernito, of this report. Complementary and road conservation works are supervised by Engineer José Mena Carmona.

Point N°1: *Slope with pending strengthening measures*



Location
North Lambert projection:
E: 499554
N: 324579

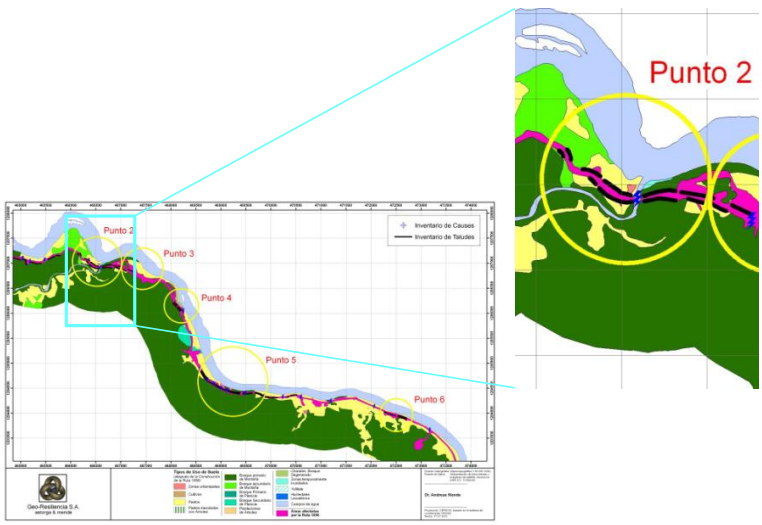
Benching was performed at this point to create the slope and prevent landslides. A coconut fibre blanket is being placed to control sediment, in addition to the use of hydroseeding and top ditches to control the surface runoff on this slope, making it impermeable and eliminating the displacement of sediment. A silt fence will also be placed as precaution, so that it will retain sediment in the event that it is displaced.

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point N°2: *Río Infiernito, slopes to be protected and created*



Location
North Lambert Projection:
E: 502973
N: 321544

Landslides are being removed in this sector, due to the instability of the slopes, in addition to cleaning of the lined ditch to recover its adequate hydraulic function.

Additional works to be performed during the following months

Description:

The following works will be performed after concluding the intervention at the points indicated by the technical team, which mainly consist of hydraulic improvement of several points in this sector, namely: improvement of water passages through the construction of drains with the corresponding protections (headings, buttresses, skirt-boards), construction of lined ditch, construction of step drains and placement of Silt Fence. There are also some works to clean channels and ditches.

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point A: (Cleaning of ditch, removal of landslide)

North Lambert coordinates:
E: 499892
N: 323218

A landslide was removed at this point, caused by an inadequate slope structure. The lined ditch was also cleaned to maintain its adequate hydraulic function.

Hydro-seeding will be used in this sector to treat this slope, to improve its stability. A lined ditch will also be built at certain points affected by the landslide. See pictures below:

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point B (Construction of Drain): North Lambert Coordinates:
E: 499560
N: 324228

A drain with a 1,50m diameter will be placed in this sector, with the corresponding protection (headings, buttresses, skirt-boards), and a 10m transversal section of the road. See picture below:

Point C (Construction of Drain): North Lambert Coordinates:
E: 499650
N: 323870

A drain with a 1,50m diameter will be placed here, with the corresponding protections (headings, buttresses, skirt-boards), and a 10m transversal section of the road. See pictures below:

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point D (Repair of hole in log bridge):

North Lambert coordinates:
E: 499777
N: 323555

This sector requires the repair of a hole in Tucas bridge. See picture below:

Point E (Construction of Drain):

North Lambert coordinates:
E: 499986
N: 323171

A drain with a diameter of 1m will be placed here, with the corresponding protections (headings, buttresses, skirt-boards), and a 10m transversal section of the road. See picture below:

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point F (Repair of hole in log bridge):

North Lambert Coordinates:
E: 500256
N: 322867

This sector requires the repair of a hole in the log bridge, and cleaning of the channel (since logs are obstructing the course of the river).

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point G (Cleaning of channel and ditch): North Lambert Coordinates:
E: 500445
N: 322614

This sector requires cleaning of the drain structure connecting with the channel and cleaning of the lined ditch on the right side. See pictures below:

Point H (Construction of drain): North Lambert Coordinates:
E: 321839
N: 500887

A drain with a 1,50m diameter will be placed in this sector, with the corresponding protection (headings, buttresses, skirt-boards), and a 10m transversal section of the road.

Point I (Construction of step drain): North Lambert Coordinates:
E: 321689
N: 501233

A step drain will be built in this sector to prevent undermining due to rain water circulating on the ditch, which could cause damages to the existing pavement structure. See pictures below:

Translation into English

(CONAVI logo)

Executive Directorate
Tel. (506) 2202-5563 Fax: (506) 2253-3584
Email: cristian.vargas@conavi.go.cro

Point J (Construction of lined ditch and placement of Silt Fence):

North Lambert coordinates:
E: 501394
N: 321653

A lined ditch will be built at this point, along 330m, not continuous, and a silt fence will be placed to control the displacement of sediment. See pictures below:

ANNEX 9

Professor Colin Thorne

'Report on the Risk of Irreversible Harm to the Río San Juan relating to the Construction of the Border Road in Costa Rica'

4 November 2013

CASE CONCERNING

CONSTRUCTION OF A ROAD IN COSTA RICA ALONG THE SAN JUAN RIVER

(NICARAGUA v. COSTA RICA)

Report on the Risk of Irreversible Harm to the Río San Juan relating to the Construction of the Border Road in Costa Rica

Prepared by

Colin Thorne
Nottingham, UK

Professor and Chair of Physical Geography
University of Nottingham

4 November 2013

Table of Contents

1. INTRODUCTION 3

2. MY QUALIFICATIONS 3

3. TERMS OF REFERENCE 4

4. METHODOLOGY 5

5. CONTRIBUTION OF SEDIMENT FROM THE ROAD TO THE RÍO SAN JUAN 7

5.1 OVERVIEW 7

5.2 IS THERE EVIDENCE OF A SURGE IN SEDIMENT LOAD IN THE RÍO SAN JUAN SINCE DECEMBER 2010? 8

5.3 IS THE 1 M Y^{-1} RATE OF LAND LOWERING ESTIMATED IN THE 2012 KONDOLF REPORT REASONABLE? 13

5.4 ARE CALCULATED DELIVERY RATES FOR ROAD–DERIVED SEDIMENT BASED ON THE RESULTS OF FIELD MONITORING SUFFICIENT TO CAUSE "SIGNIFICANT" OR "IRREVERSIBLE" DAMAGE TO THE RÍO SAN JUAN?..20

5.5 POTENTIAL FOR ROAD-DERIVED SEDIMENT TO IMPACT THE RÍO SAN JUAN 22

5.5.1 Introduction 22

5.5.2 Estimated annual load of Road-related sediment supplied to the Río San Juan 23

5.5.3 Average annual sediment load in the lower Río San Juan since December 2010 24

5.5.4 Input of Road-derived sediment to the Río San Juan 25

5.5.5 Potential impact on sedimentation in the lower Río San Juan 25

5.5.6 Inputs of Road-derived sediment are not just insignificant, they are undetectable 26

6. RESPONSE TO NEW EVIDENCE SUBMITTED BY NICARAGUA 27

7. MY OBSERVATIONS OF MITIGATION WORKS ON THE ROAD IN MAY 2013 37

8. CONCLUSIONS ON THE RISK OF IRREVERSIBLE HARM TO THE RIVER 41

9. REFERENCES 42

10. STATEMENT OF INDEPENDENCE AND TRUTH 43

1. Introduction

1. I am Colin Thorne, Professor of Physical Geography at the University of Nottingham. I have been requested by Costa Rica to prepare an independent expert report for the International Court of Justice (the ***Court***) in connection with the Request for New Provisional Measures submitted by Nicaragua on 11 October 2013 (the ***Request***) in the *Case Concerning Construction of a Road in Costa Rica along the San Juan River (Nicaragua v Costa Rica)* (the ***Road Case***).

2. I am instructed to form an independent expert opinion on the matters set out in the Terms of Reference below.

2. My Qualifications

3. I hold the Chair of Physical Geography at the University of Nottingham, UK. I have BSc and PhD degrees in Environmental Science from University of East Anglia, UK. I have over 35 years professional experience in matters relating to rivers, river sedimentation and river morphology. My research concentrates on fluvial hydraulics and sediment transport in natural, modified and managed rivers, particularly with respect to the implications for erosion, sedimentation, flood risk and the river environment.

4. I have previously submitted an independent expert report in the *Certain Activities* Case: "Assessment of the physical impact of works carried out by Nicaragua since October 2010 on the geomorphology, hydrology and sediment dynamics of the San Juan River and the environmental impacts on Costa Rican territory", which is Appendix 1 to Costa Rica's Memorial in the *Certain Activities* Case (the ***First Report***). I also submitted a second independent expert report in the *Certain Activities* Case, relating to Costa Rica's Request for Provisional Measures, dated 24 September 2013. That report is entitled "Report on the Impact of the Construction of two New Caños on Isla Portillos" and dated 10 October 2013 (the ***Second Report***).

3. Terms of Reference

5. I am instructed to form an independent expert opinion on allegations of fact made in the Request that pertain to delivery of sediment derived from erosion of the Road (including slopes adjacent to the Road and disturbed areas) and the degree to which the Road poses an imminent risk of irreversible harm to the Río San Juan.

6. In the Request, Nicaragua makes various statements concerning the risks posed to the Río San Juan by the Road. Specifically:

(i) Page 1, paragraph 2, final sentence,

'Costa Rica's road works have caused a surge in the San Juan River's sediment load requiring Nicaragua to take active efforts, including dredging, to maintain the capacity and quantity of the river's waters.'

(ii) Page 2, paragraph 3,

'construction by Costa Rica of a 160 km road running along the margin of the San Juan River.'

(iii) Page 2, paragraph 5, sentences four to six,

'They (the team sent by Nicaragua to inspect the River in October 2012) confirmed that Costa Rica had not taken measures to stop or even mitigate the serious harm caused to the San Juan de Nicaragua River. Furthermore in anticipation of the second heavy rainy season since the construction of the Road began, Nicaragua sent the same team on a second mission in May 2013. The second mission underscored the urgent need for mitigation measures previously presented by Nicaragua to the Court.'

(iv) Page 3, paragraph 2,

*'As the rainy season enters into its heaviest stage washing even greater quantities of sediment and run-off into the river's waters, Costa Rica still has not provided the necessary information to Nicaragua, nor has it taken the necessary actions along the 160 km road to avoid or mitigate the irreparable damage that is being inflected [*sic*] on the river and its surrounding environment, including*

navigation and the health and wellbeing of the population living along its margins.'

7. I have been asked to consider the accuracy of these statements, bearing in mind what has already been set out in Nicaragua's pleadings in the *Road Case* (including in the Report of Professor Kondolf (the ***2012 Kondolf Report***, referred to in paragraph 9 below), and with a particular view to the risk of irreversible harm to the San Juan River.

8. I have also been asked to review and comment upon the documents submitted by Nicaragua to the Court on 1 November 2013 in support of its Request. These are:

   (a) *Confirmation of Urgent Measures to Mitigate Erosion & Sediment Delivery from Rte 1856, Costa Rica, into the Río San Juan, Nicaragua*, a report by Dr Kondolf dated 12 October 2013 (***Annex 1***);

   (b) *Continued Impacts of Erosion from Rte 1856, Costa Rica to the Río San Juan, Nicaragua*, a further report by Dr Kondolf dated 30 October 2013 (***Annex 2***); and

   (c) *Selected Photographs of Depositional Features along the Río San Juan de Nicaragua caused by Costa Rican Route 1856 Construction, Poor Design and Lack of Maintenance. Photos taken May 20-22, 2013* (***Appendix A***), which accompanies Annex 2.

   My primary comments on these documents are set out in Section 6 below.

4. Methodology

9. In this report I collate and present the relevant outcomes to date of work performed in two ongoing scientific and engineering studies that I requested be undertaken in February 2013 and for which I continue to provide technical leadership. These reports are: *Report on hydrology and sediments for the Costa Rican river basins draining to the San Juan River*. Costa Rica Institute of Electricity, Centre for Engineering Studies, Department of Hydrology, San José, Costa Rica (the ***ICE Report***), which has been submitted as **Attachment CR-1**; and *Systematic Field monitoring of*

Erosion and Sediment Yield along Route 1856. University of Costa Rica, Faculty of Engineering, School of Civil Engineering (the ***UCR Report***), which has been submitted as **Attachment CR-2**. These studies have been undertaken to provide data to inform my review of the Report prepared by G. Mathias Kondolf entitled, *Environmental Impacts of Juan Rafael Mora Porras Route 1856, Costa Rica, on the Río San Juan, Nicaragua*, December 2012 (the ***2012 Kondolf Report***), which is Annex 1 to Nicaragua's Memorial in the *Road Case*.

10. I also draw upon observations and knowledge gained through research undertaken in preparing a report that will accompany Costa Rica's Counter Memorial in the *Road Case* that has included:

(a) participating in two site visits to the Road, on 15 and 16 February, and 7 May 2013. On the first occasion I drove along and/or viewed from the air the entire length of the Road. On the second occasion I drove to and reviewed from the air the first 41 km of the Road between Marker II and Boca San Carlos. During both site visits I undertook field observations, spoke to engineers and scientists engaged in mitigation works and took ground and aerial photographs;

(b) requesting, formulating and supervising scientific and technical studies performed by qualified Costa Rican scientists and engineers, to elicit the data and information needed to evaluate the potential for construction of the Road to impact the Río San Juan;

(c) holding technical meetings with the team of scientists and engineers on February 14 and 17, May 6 and 9-10, and July 30-31, during which we discussed approaches and methodologies to be employed in performing the work, reviewed progress and discussed the results of archive-based, field, remote-sensing, GIS-based research, and computer modelling; and

(d) reviewing and challenging the preliminary findings of the team and requesting additional analyses where appropriate.

11. Where I rely on information and data contained in the ICE and UCR Reports, or any other reports prepared in the course of the investigations and activities referred to in paragraph 10 above, I indicate that I am doing so.

5. Contribution of sediment from the Road to the Río San Juan

5.1 Overview

12. In my opinion, Nicaragua's estimates of the contribution of sediment to the San Juan River from the Border Road have been over-estimated and indeed are massively overstated. In my view, the contribution of sediment from Road to the River cannot be said to pose any risk of significant, let alone irreversible, harm to the River.

13. My opinion is based on the outcomes of scientific studies (reported in detail in below) which indicate that:

    (a) there has been no measurable surge in the San Juan River's sediment load since construction of the Road (see section 5.2 below);

    (b) the estimate for rate of land surface lowering due to erosion of cut and fill slopes along the Road made in the 2012 Kondolf Report (1 m y^{-1}) is a significant overestimate (see section 5.3 below);

    (c) sediment input from the Road, including sediment eroded by mass wasting, is nowhere near sufficient to cause significant, let alone irreversible, damage to the Río San Juan (see section 5.4 below); and

    (d) even if the additional input of sediment from the Road estimated in the 2012 Kondolf Report was accurate (which it is not), there would still be no impact on navigation in the lower Río San Juan that would require Nicaragua to take active efforts including dredging (see section 5.5 below).

14. At the outset, it is important to bear in mind that the Río San Juan drains a large catchment that produces a significant but highly variable amount of sediment every year and to recognise that the River has a the capacity to process that sediment annually. This is explained further in paragraph 16 below. For these reasons,

comparisons with streams like the Clearwater River in the United States are inapt.[1] Furthermore, given these particular characteristics of the Río San Juan, analogies with fish species such as salmon are also inapt, because the species of fish occupying the San Juan are naturally adapted to high and variable concentrations of sediment.[2]

5.2 Is there evidence of a surge in sediment load in the Río San Juan since December 2010?

15. To ascertain whether there is evidence to support Nicaragua's assertion that there has been a surge in the San Juan River's sediment load since construction of the Road, I examined available records of measured Suspended Sediment Concentration (***SSC***) in the Río San Juan – Río Colorado system prior to and following construction of the Road.

16. The Río San Juan drains a large catchment (~40,000 km^2) that includes areas of high, steep and naturally unstable terrain (including active volcanoes), and which receives abundant but highly variable amounts of rainfall distributed unevenly throughout the basin and the year. The physical attributes of its basin dictate that it transports a heavy, but highly variable sediment load. SSC records from Station 6901-03 at La Trinidad between January 1974 and March 1976,[3] and Station 6911-04 at Delta Colorado, between December 2010 and June 2013, demonstrate both the high concentrations and variability of sediment in the River. These records represent periods prior to and since construction of the Road. SSCs measured at these two stations should be comparable because over 90% of the flow and sediment that

---

1 Cf Annex 2, p. 8.

2 Cf Annex 2, pp. 2 and 8.

3 These data are used because they are the only suspended sediment records available to the technical team for the Río San Juan under pre-Road conditions. I am instructed that these measurements were made jointly by Costa Rica and Nicaragua and their source is: Governments of Nicaragua and Costa Rica (1977). Central American Hydrological Project [PHCA), with the assistance of the United Nations Development Programme, San Juan River Hydroelectric and Navigation Project, December 1977, volume 1, page 69. These data were cited in Nicaragua's Counter Memorial in the *Navigational Rights Case*, "the sediment load immediately downstream from the Sarapiquí River, measured at the beginning of the seventies, was 10.2 million metric tons per year." See Nicaragua Counter-Memorial, *Navigational Rights Case*, para. 1.1.8.

passes through the La Trinidad also passes through the Delta Colorado Station. Station locations are shown in Figure 1 below and records are listed in Table 1.

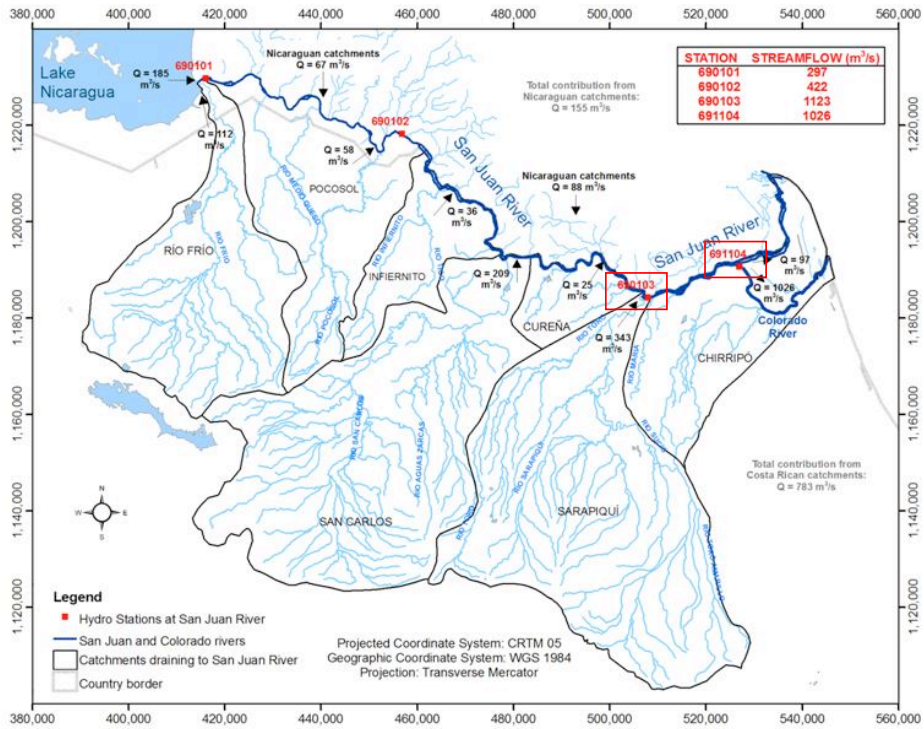


Figure 1. Gauging stations and mean annual discharges in the Río San Juan - Colorado system with La Trinidad and Delta Colorado Stations highlighted (from the ICE Report).

Table 1. Suspended sediment records for the Río San Juan – Colorado (from the ICE Report).

Station code	Name	Basin	River	No. of samples	Sampling period	Ave. Annual Suspended load (t yr^{-1})
01-03	La Trinidad	San Juan	San Juan	12	1974-1976	7 995 000
11-04	Delta Colorado	San Juan	Colorado	31	2010-2013	5 981 000[a]

[a]Note: this is the average annual suspended load in the Río Colorado downstream of the Delta.

17. To allow comparison, these records are plotted together on a single graph, with rating curves for SSC as a function of discharge for each station and period being added using regression (Figure 2).

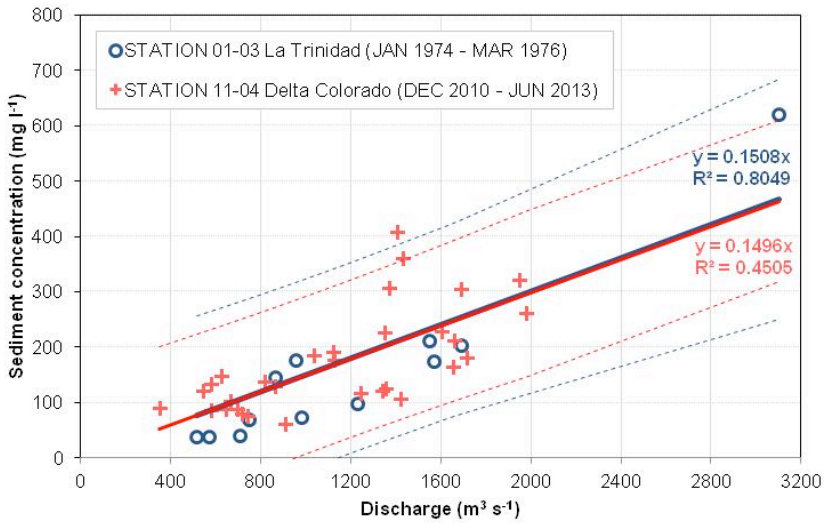


Figure 2. Measured suspended sediment concentrations, rating curves and 95% confidence intervals for pre-Route 1856 [La Trinidad (01-03), January 1974 to March 1976] and post-Route 1856 [Delta Colorado (11-04), December 2010 to June 2013] periods. Continuous lines are SSC Rating Curves (based on best-fit regression). Dotted lines indicate the 95% confidence intervals for each regression curve (from the ICE Report).

18. If additional sediment from the Road had caused a surge in the rate of sediment transport in the Río San Juan, this would reflect in Figure 2 through increases in the SSCs measured since 2010 and a corresponding upward shift in the 2010-2013 suspended sediment rating curve compared to that for 1974-1976. It is clear from Figure 2 that this is not the case.

19. On the contrary, the highest measured concentration (SSC > 600 mg l^{-1}) was actually observed during the period *prior to* construction of the Road and the distribution of 27 of the 31 post-Road measured concentrations in Figure 2 coincides with that of the pre-Road data. Not only is there no statistically significant difference between the pre- and post-Road suspended sediment rating curves, Figure 2 reveals them to be practically identical. This suggests that any differences between pre- and post-Road SSCs measured at these stations are the result of random chance.

20. Additionally, the high degree of natural variability in the relationship between discharge and suspended sediment concentration means that the 95% confidence intervals on the rating curves are wide apart. Not only is natural variability similar during the pre- and post-road periods, but the two uncertainty bands are also close

to coinciding. This illustrates that variability in measured SSCs has not changed significantly between pre- and post-Road periods and that differences between measured values are probably due to random chance.

21. As discharge is measured on a semi-continuous basis at these hydrometric stations, the suspended sediment rating curve can be integrated with the discharge record to calculate the mean annual suspended sediment load. This approach was used to calculate the mean annual suspended sediment loads transported by the Río San Juan at La Trinidad between 1974 and 1976; 7 995 000 t yr^{-1}, and by the Río Colorado at Delta Colorado between 2010 and 2013: 5 981 000 t yr^{-1} (as listed in Table 1).

22. The average discharges measured at the La Trinidad and Delta Colorado stations listed in Table 2 are 1 123 m^3 s^{-1} and 1 026 m^3 s^{-1}, respectively. This suggests that, on average, ~91% of the discharge in the Río San Juan approaching Delta Costa Rica passes to the Río Colorado, while ~9% passes to the lower Río San Juan. As the suspended load is distributed throughout the River's flow, it is reasonable to assume that the suspended sediment load is similarly divided.

23. On this basis the suspended load measured in the Río Colorado at the Delta Colorado station may be adjusted to represent that in the Río San Juan upstream of the Delta by multiplying it by the reciprocal of 0.91. Applying this adjustment, the average annual suspended load in the Río San Juan between December 2010 and June 2013 was approximately 6 573 000 t yr^{-1}. It follows that the mean annual suspended load in the lower Río San Juan during this period was about 592 000 t yr^{-1}.

24. In considering these figures, it must be borne in mind that they are based on small numbers of samples made over short (two to three-year) periods of observation. The 95% confidence intervals of the regression relationships used to generate the suspended sediment rating curves reflect not only uncertainty due to the small number of data points, but also the high degree natural variability inherent to the way that SSCs vary with discharge in the Río San Juan.

25. Recognising this, uncertainty analyses were performed on the data for both stations to produce 95% confidence intervals for the calculated mean annual suspended

sediment loads in the Río San Juan. The results are listed in Table 2 and illustrated in Figure 3.

Table 2. Mean annual suspended sediment loads in the Río San Juan – Colorado (from the ICE Report)

River	Period	Mean Annual Suspended Sediment Load (t yr^{-1})	
		Best Estimate	95% Confidence Interval
San Juan	1974 - 1976	7 995 000	5 405 000 - 10 585 000
San Juan	2010 - 2013	6 573 000	5 181 000 - 7 966 000
Colorado	2010 - 2013	5 981 000	--
Lower San Juan	2010 - 2013	592 000	--

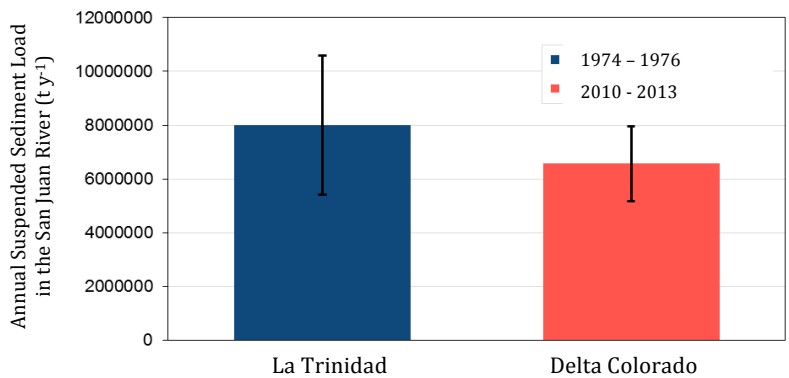


Figure 3. Mean annual suspended sediment loads in the Río San Juan based on measurements at La Trinidad (1974-1976) and Delta Colorado (2010-2013). Vertical black lines indicate 95% confidence intervals. Note that the loads based on measurements at Delta Colorado station have been adjusted to represent the Río San Juan on the basis that at the Delta suspended load is divided in the same proportion as discharge (from the ICE Report).

26. In comparing the suspended sediment loads transported annually by the River during the two periods of observation, the first point to note is that the best estimate of the mean for 2010-2013 is noticeably *lower* than that for 1974-1976. This is unsurprising, because the post-Road period has been drier than usual. For example, measured data for the hydrometric El Bum station (69-578) indicate that mean annual rainfall in the hydrological year 1975-1976 was 3 651 mm, compared to only 2 267 mm in the hydrological year 2011-2012. Lower rainfall produces less catchment runoff that generates less erosion and, therefore, a smaller suspended load.

27. However, it is instructive to consider that the difference between the mean annual suspended loads falls within the confidence intervals on those means (listed in Table 2). As the over-lapping confidence intervals in Figure 3 confirm, the high levels of measurement uncertainty and natural variability in annual suspended sediment loads mean that there is no statistically significant difference between mean annual suspended sediment loads for periods prior to and following construction of the Road.

28. The point is that, notwithstanding the difference in calculated loads, analysis of the measured data indicates that they are not *significantly* different. Statistically, there is a 95% probability that the two sample means come from the same population of annual suspended sediment loads, a population that is characterised by a very high degree of inter-annual variability. It must, therefore, be concluded that the difference between them is statistically insignificant.

29. The data reveal that measurement uncertainty, together with natural fluctuations in rainfall, discharges, catchment sediment yields and SSCs, mean that suspended sediment loads are likely to vary inter-annually between about 5 and 10.5 million tonnes. Using longer measurement records with more measurements would probably reduce the confidence interval on the mean annual suspended load somewhat, but the range of expected loads would remain wide because high natural variability is a property of the River, not the data.

30. The significance of this finding is that it demonstrates that no possibility exists for using measured loads to prove the existence of a surge in sediment transport in the Río San Juan, unless that surge produces a truly exceptional annual suspended load – meaning something greater than around 10.5 million tonnes.

5.3 Is the 1 m y^{-1} rate of land lowering estimated in the 2012 Kondolf Report reasonable?

31. In the 2012 Kondolf Report, Dr Kondolf concludes that *'landslide/gully erosion averages 1 m deep (i.e., lowering of the land surface by 1 m on average'* (2012 Kondolf Report, page 46). Using this estimate, Dr Kondolf concludes a sediment input

of 87 000 to 109 000 $m^3 y^{-1}$ (2012 Kondolf Report, page 46). This estimate is repeated in Annex 2 (on page 2). It is an estimate for *all* sediment delivered from slopes and other disturbed areas along the Road to the River, whether by mass wasting or gullying. In the 2012 Kondolf Report erosion of the road bed itself is dismissed as being less than 10% of that from slopes and in Annex 1 Dr Kondolf notes that most of the road bed is now gravelled, which will further reduce erosion of the road itself, especially in relation to erosion of cut and fill slopes.

32. To establish whether rate at which the land surface is being lowered by erosion of cut slopes, fill slopes and other disturbed areas along the Road adopted in the 2012 Kondolf Report (1 m y^{-1}) (taken from the 2012 Kondolf Report, page 46) is conservative, or even reasonable, a team from the University of Costa Rica has, since 8 June 2013, been monitoring erosion at nine of the most active sites for sheet erosion, rill (micro-channel) erosion, landslides and gullying along the Road between Marker II and the Río Infiernito (Figure 4).

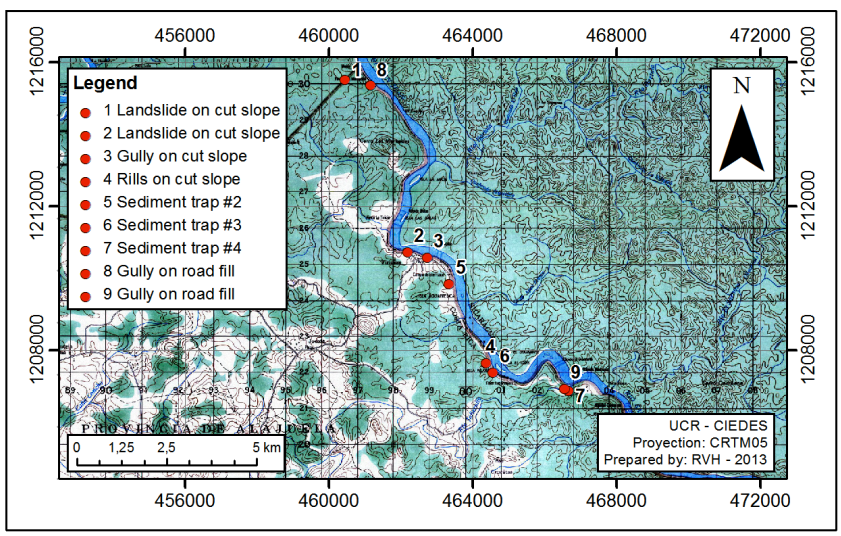


Figure 4. Location of monitored sites (from the UCR Report).

33. The monitoring results reported here come from the two largest rotational landslides observed along the Road; the three large gullies; the slope which displayed most intense rill (micro-channel) erosion; and a sediment trap that collects sediment eroded from a steep stretch of road bed and cut slope which only

experiences sheet erosion (Figures 5 and 6). Hence, it is reasonable to assume that the recorded rates of land surface lowering represent 'worst case' scenarios for Road-related erosion to date.

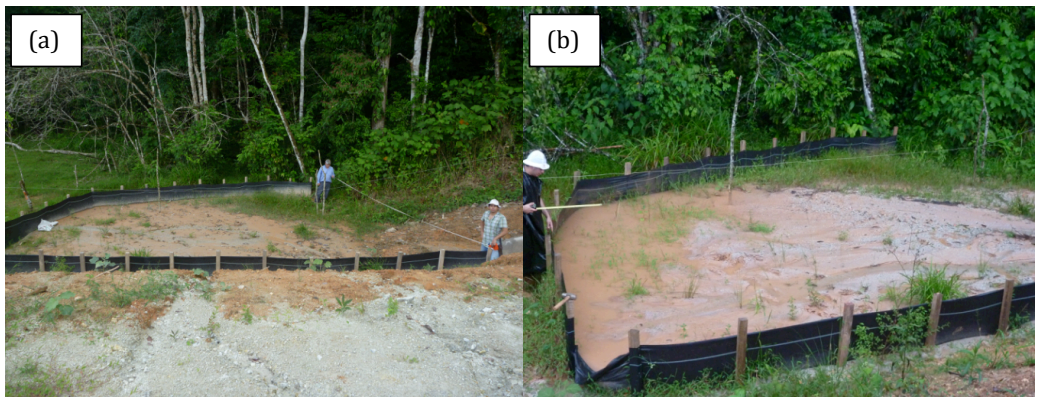


Figure 5. Sediment trap #2 on (a) 8 June and (b) 22 July 2013 (from the UCR Report).

Figure 6. Rill erosion monitoring site on a cut slope, with rills numbered and 1 metre grid overlaid for scale (from the UCR Report).

34. Based on field measurements, the rate of land surface lowering due to sheet erosion of the road bed and cut slopes varies between about 0.061 and 0.095 m y^{-1}. The range in the rates is due to differences in the amount of soil lost between re-surveys of features made during relatively dry (June - July) and relatively wet (July - August) periods in 2013. Based on these direct measurements it is concluded that using

0.095 m y^{-1} to represent the average annual rate of lowering of the land surface due to sheet erosion is conservative.

35. On the monitored cut slopes where landslides were observed, they occupied 10% to 13% of the overall area of the slope and had lowered the land surface in those areas by between 0.11 and 0.38 metres. It is reasonable to assume that the slopes were created when the Road was under construction in 2011, in which case, they have now existed for at least two years. This implies average rates of lowering of the land surface due to landslides of between 0.06 and 0.19 m y^{-1} when averaged over the entire areas of the slopes affected.

36. Gullies on cut slopes were the rarest erosion feature observed by UCR along the Road between Marker II and the Río Infiernito, while rills were the most common. The worst gully monitored in the study had a maximum depth of 3 metres and a surface area of 13.1 m^2, meaning it covered only just over 2% of the slope in which it had formed. The total volume of soil eroded to create this gully was approximately 6 m^3. When this volume is divided by the total area of the slope, the average lowering of the land surface due to erosion by this gully is 0.01 m. If it is again assumed that the slope was created when the Road was under construction in 2011, this implies a rate of lowering of the land surface due to gullying is 0.005 m y^{-1}, when averaged over the entire area of the slope affected.

37. The majority of slopes along the Road between Marker II and the Río Infiernito experience rill erosion. At the rill study site, there were 26 rills, the largest of which had a maximum width of 0.3 metres and a maximum depth of 0.6 metres. Based on spatial analysis of all the rills in the sample area, and with the conservative assumption that they *all* had widths and depths equal to that of the largest rill, UCR concluded that rill erosion has lowered the land surface of the slope by an average of 0.12 metres. Again assuming that the slope was created when the Road was under construction in 2011, this implies an average rate of lowering of the land surface due to rilling of around 0.06 m y^{-1} when averaged over the entire area of the slope. As the UCR study site was the most intensely rilled slope observed, this represents the 'worst case' example of rill erosion in their study area.

38. Fill slopes in the studied area do not feature erosion due to deep landslides, with mass wasting limited to much less damaging shallow slips and soil falls. Rill erosion is observed on fill slopes, and the rate monitored on the most intensively rilled cut slope may be conservatively used to represent rill erosion of fill slopes as well.

39. Gully erosion on fill slopes was observed by UCR to cover about 4% to 10% of the monitored fills, lowering the surface of these slopes by between 0.06 and 0.10 m when averaged over the area of fill slope affected. In contrast to erosion of road cuts, the monitored gullies had formed in about six months. Therefore, the estimated average annual rate of land surface lowering due to gully erosion of fill slopes is higher than that for cut slopes, being between 0.12 and 0.20 m y^{-1}.

40. Table 3 below summarises the observed average erosion depths and average annual rates of land surface lowering mentioned above. As this summary lists the highest values of eroded area/area of feature, average eroded depth, and average annual rates of land surface lowering for each erosion type, the data listed are likely to over-estimate actual average values for the Road between Marker II and the Río Infiernito and, in this respect, they are conservative.

Table 3. Summary of erosion monitoring results (from the UCR Report).

Type of feature	Erosion type	Eroded Area/Area of Feature (%)	Average erosion depth (m)	Average rate of land surface lowering (m y^{-1})
Cut Slope	Landslide	13	0.38	0.19
Cut Slope	Gully	2	0.01	0.005
Cut Slope*	Rill	50	0.12	0.06
Road bed and Cut Slope	Sheet	100	0.02	0.095
Fill Slope	Gully	9	0.10	0.20

*these findings may also be conservatively applied to rills on fill slopes.

41. The UCR further recommend using average erosion depths for landslides, gullies and rills on cut slopes in place of estimated annual rates of land surface lowering when calculating Road-related erosion and potential sediment yield to the Río San Juan, as doing so is even more conservative. For sheet erosion, the maximum rate observed

(i.e. 0.095 m y^{-1} during the wet season) is recommended. Finally, 0.20 m y^{-1} is the most conservative value for gullies in road fills and UCR suggests that this should be used. These rates should all over-estimate actual average erosion to date, but considering that the last two years have been drier than average, they could be exceeded in future. This will only be the case if erosion risks are unmitigated, leaving the slopes exposed to potentially heavier rainfall. As discussed in Section 7 below, and reported in **Attachments CR-3 and CR-6,** work to mitigate erosion risks has begun and will continue as necessary.

42. In the 2012 Kondolf Report, rates of land surface lowering due to erosion were estimated using visual observations of the Road made at a distance from the air and from a boat during a single, two-day visit to the area in October 2012, together with consideration of published studies of sediment budgets in the Pacific Northwest of North America and the team's observations of road-related erosional impacts elsewhere (2012 Kondolf Report, page 46). In his Report, Dr Kondolf states that, '*we conservatively estimated that that landslide and gully erosion is occurring on 40-50% of the steep disturbed land (21.8 to 27.3 ha) and that this landslide/gully erosion averages 1 m deep (i.e., lowering the land surface by 1 m on average*) (2012 Kondolf Report, page 46).

43. Monitoring of landslide and gully erosion reported by UCR above suggests that the rate of land surface lowering estimated in the 2012 Kondolf Report is probably too high by a factor of five. Further, UCR field monitoring indicates that landslides and gullies on average cover around 10 to 15% of the slopes with these features, so the 40 to 50% estimate of the area of the Road on which this erosion is occurring which is adopted in the 2012 Kondolf Report would also appear to be significantly too high.

44. In my experience, including my inspections of the Road in February and May 2013, of land surface lowering due to landslides and gullies averaging 1 m y^{-1} is too high and it is unlikely to be accurate. Also, the assumption that landslides and gullies cover 40 to 50% of slopes and other disturbed areas overstates the extent of these features. Conversely, the monitored rates and areas affected as summarised in Table 3 are entirely reasonable and, in my opinion, more reliable.

45. Recognising this, the average annual sediment yield due to landslide and gully erosion between Marker II and Boca San Carlos (i.e. the upstream 41.6 km of the Road that runs adjacent to the River) estimated by Dr Kondolf (reported on page 46 of the 2012 Kondolf Report) of 218 400 to 273 000 $m^3 y^{-1}$ is likely to be too high.

46. In Annex 2, which is discussed further in Section 6 below, Dr Kondolf emphasizes the impact of 'mass wasting' which he describes as involving *'the movement of larger volumes of earth by gravity, often along failure plains determined by differences in material, such as the boundary between a volume of fill material and the existing slope upon which it was placed.'* (Annex 2, page 9.) I agree in principle with this description. Dr Kondolf also states that, on his inspection in October 2013, *'[s]ignificant cutslope and fillsope [sic] mass wasting as also locally evident'* (Annex 2, page 14). However, the 'mass wasting' Dr Kondolf is said to have observed in October 2013 has not caused him to revisit his estimates of sediment input to the Road, which, as noted in paragraph 31 above, includes all sediment input, whether from mass wasting or otherwise.

47. All forms of mass wasting (including landslides) are driven by gravity. In short the weight of the slope becomes greater than its strength and it falls down. Failure may be triggered by any of the processes listed as triggering landslides in the UCR Report, on page 14. Essentially there is a range of mechanisms by which slopes retreat due to mass wasting, with landslides being the largest in scale and shallow slides being the smallest. In the studies made by UCR and ICE, which yield the estimates for sediment input described in Table 3 above, all mass wasting is treated as being by landslides. As a result, the estimates for sediment input are conservative, because landslides are the largest in scale of the potential events which result in mass wasting. Furthermore, it is clear that these estimates take account of all potential sediment input from the Road to the River, including by mass wasting. The potential for this sediment input to cause damage to the San Juan River is discussed further in Section 5.4 below.

5.4 Are calculated delivery rates for Road–derived sediment based on the results of field monitoring sufficient to cause "significant" or "irreversible" damage to the Río San Juan?

48. To investigate whether sediment eroded from the Road could pose any risk to the Río San Juan, the ICE Report took up the results of erosion monitoring reported in the UCR Report to estimated sediment delivery rates from the Road to the River. The work was performed in two steps. First, the data in Table 3 were adopted to represent average annual rates of land surface lowering, as recommended in the UCR Report. ICE then used the length and steepness of the road bed, and the areas of cut slopes, fill slopes and other disturbed ground along the full length of the Road adjacent to the River between Marker II and Delta Costa Rica to convert annual average rates of land surface lowering into annual eroded volumes.

49. The results are summarized for each of the five main river basins draining from Costa Rica to the Río San Juan between Marker II and Delta Costa Rica, in Table 4.

Table 4. Estimated average annual erosion rates for the Road (from the ICE Report).

Basin	Road length (km)	Annual rate by volume (m^3 yr^{-1})			Annual rate by mass* (t yr^{-1})		
		Road	Slopes	Total	Road	Slopes	Total
Major Costa Rican river basins draining directly to the San Juan River between Marker II and Delta CR							
Infiernito	38	12 260	28 000	40 260	20 450	46 750	67 250
San Carlos	11	2 060	600	2 660	3 450	1 000	4 450
Cureña	28	5 220	7 560	12 780	8 700	12 650	21 350
Sarapiquí	3	560	160	720	950	250	1 200
Chirripó	22	4 100	260	4 360	6 850	450	7 300
Costa Rican area that drains directly to the San Juan River between Marker II to and Delta Colorado							
Total	102	24 200	36 580	60 780	40 400	61 100	101 550

* To convert eroded volumes to masses, a bulk density of 1.67 t m^{-3} was assumed. This value is widely used to represent the bulk density of silt-sand soils.

50. Second, ICE applied a sediment delivery ratio to estimate the proportion of the eroded sediment reaching the Río San Juan. The 2012 Kondolf Report estimated this delivery ratio to be 0.4 (2012 Kondolf Report, page 46). However, considering the small size of many of the micro-basins draining either directly to the Río San Juan or to the five major Costa Rican tributaries, and bearing in mind the relatively fine grain

size of most of the eroded sediment (found to be mostly silt in the UCR Report), ICE concluded that Dr Kondolf's estimate was probably low and they used a higher estimate of 0.6 instead.

51. I concur with ICE's selection of 0.6 as being reasonable but more conservative than Dr Kondolf's assumption of 0.4. The results of applying this higher delivery ratio are listed in Table 5 and shown in Figure 7.

Table 5. Average annual inputs of Road-derived sediment to the Río San Juan (from the ICE Report)

Basin	Road length (km)	Input by volume (m^3 yr^{-1})			Input by mass* (t yr^{-1})		
		Road	Slopes	Total	Road	Slopes	Total
Major Costa Rican river basins draining directly to the San Juan River							
Infiernito	38	7 360	16 800	24 160	12 250	28 050	40 300
San Carlos	11	1 240	360	1 600	2 050	600	2 650
Cureña	28	3 140	4 540	7 680	5 200	7 600	12 800
Sarapiquí	3	340	100	440	550	150	700
Chirripó	22	2 460	160	2 620	4 100	250	4 350
Costa Rican area that drains directly to the Río San Juan between Marker II to and Delta Colorado							
Total	102	14 540	21 960	36 500	24 150	36 650	60 800

* To convert eroded volumes to masses, a bulk density of 1.67 t m^{-3} was assumed. This value is widely used to represent the bulk density of silt-sand soils.

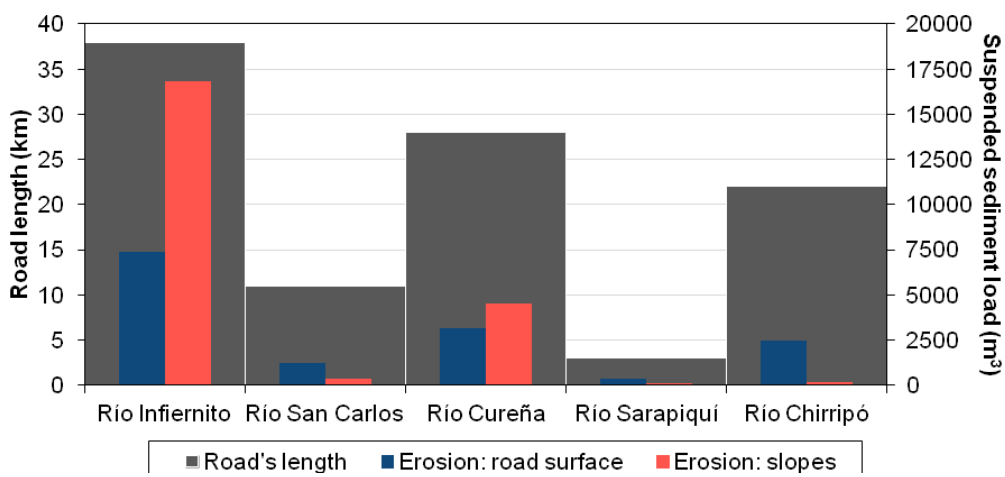


Figure 7. Estimated annual inputs of eroded sediment to the Río San Juan from the Road along the five main basins between Marker II and Delta Colorado (from the ICE Report).

52. The results indicate that delivery of sediment eroded from slopes along the Road in the San Carlos, Sarapiquí and Chirripo reaches of the Río San Juan is negligible. Input of the slope-derived sediment in the Infiernito stretch of the Road is more of an issue, which is consistent with Dr Kondolf's decision to focus his attention on that stretch in the 2012 Kondolf Report.

53. However, the estimated average annual input sediment eroded from the Infiernito reach of the Road is around 24 000 m^3y^{-1}, which is an order of magnitude less than that estimated by Dr Kondolf for the first 41.6 km of the Road between Marker II and Boca San Carlos (87 000 – 109 000 $m^3\ y^{-1}$). Indeed, the estimated input for the entire length of the Road alongside the River between Marker II and Delta Costa Rica (36 500 $m^3\ y^{-1}$) is only a third to a half of that estimated on page 46 of the 2012 Kondolf Report.

54. The average annual rates of additional sediment delivery listed in Table 5 and graphed in Figure 7 represent conditions since December 2010 and up to June 2013. The results indicate that during this period additional sediment eroded from the Road has been delivered to the Río San Juan in the Infiernito and, to a lesser degree, the Cureña reaches, but at rates insufficient to have any significant impact on the River or its surrounding environment. This is due to the relatively large size and power of the Río San Juan and its inherent capacity to accommodate and process additional sediment without perturbing either reach-scale channel morphology (which is geologically-controlled) or in-stream and riparian habitats and ecosystems (which are well adapted to high and variable sediment loads).

5.5 Potential for Road-derived sediment to impact the Río San Juan

5.5.1 Introduction

55. The purpose of this Section is to examine whether the additional Road-derived sediment supplied to the Río San Juan could cause '*irreparable damage that is being inflected [*sic*] on the river and its surrounding environment, including navigation and the health and wellbeing of the population living along its margins*' and whether '*Costa Rica's road works have caused a surge in the San Juan River's sediment load*

requiring Nicaragua to take active efforts, including dredging, to maintain the capacity and quantity of the river's waters.'. In summary, the evidence does not support either of these statements.

5.5.2 Estimated annual load of Road-related sediment supplied to the Río San Juan

56. According to the data and calculations presented in the 2012 Kondolf Report (page 46), the average total quantity of sediment supplied to the Río San Juan by the Road annually is 87 000 to 109 000 m3 y-1. As explained in paragraph 31 above, this estimate includes all potential sources of sediment input considered significant in the 2012 Kondolf Report (a finding not revisited in Annex 2), including surface erosion and mass wasting.

57. Dr Kondolf's estimate is based on a 3-day fieldtrip during October 2012, during which he observed the Road from a helicopter and boat on the Río San Juan, but made no measurements of erosion or sediment delivery. It should be noted that Dr Kondolf's figure applies only the first 41.6 km of the Road between Marker II and Boca San Carlos. He made no estimate of erosion from the remaining ~60 km between Boca San Carlos and Delta Costa Rica, nor did he suggest that his estimate for the first 41.6 km could be upscaled to apply to the entire length of the Road between Marker II and Delta Costa Rica. In my opinion, to upscale his estimate would be unreasonable because, as Dr Kondolf noted, 43 of the 54 locations where he allegedly observed Road-derived sediment to have entered the Río San Juan are within the first 41.6 km, with only 11 along the remaining length of the Road. Having inspected the entire length of the Road, I conclude that Dr Kondolf did not upscale his estimate based on the entire length of the Road because to do so would grossly exaggerate the total input of Road-derived sediment. On this basis, the upper bound of Dr Kondolf's estimated range seems likely to be close to what he would have estimated for the entire Road.

58. As reported in section 5.4 above the Costa Rican technical team's estimate for the total quantity of Road-derived sediment delivered to the River by volume is

36 500 m^3 y^{-1}, which is only a third of the upper bound of the range estimated by Dr Kondolf.

59. As stated earlier, based on wide experience in both field observation and erosion monitoring, my view is that Dr Kondolf's use of 1 m y^{-1} as the average rate of lowering of the land surface due to landsliding and gullying is certainly an over-estimate. My observations along the entire length of the Road likewise indicate to me that Dr Kondolf's estimate that 40 to 50% of slopes are covered by landslides and gullies is also an over-estimate.

60. Notwithstanding this, to determine whether the input of Road-derived sediment could impact the environment of the Río San Juan and navigation in the *lower Río San Juan*, I have been instructed to proceed on the basis of Dr Kondolf's estimate of average annual sediment delivery of road-derived sediment, which is two to three times higher than the estimate made in the ICE Report. This exercise does not imply acceptance of Dr Kondolf's estimate, which, for the reasons I have explained, I consider to be a significant over-estimate.

5.5.3 Average annual sediment load in the lower Río San Juan since December 2010

61. Sediment loads in the River are expressed by mass (tonnes) rather than volume (cubic metres). Hence, it is necessary to convert Dr Kondolf's estimate from a volume per year to a mass. As noted in Tables 4 and 5 above, a cubic metre of sediment has a mass of about 1.67 tonnes. This is typical for closely-packed, quartz sand grains, though it may be a little high for soil (which has a higher porosity). Hence, it is in that respect conservative. Assuming that each cubic metre of soil has a mass of 1.67 tonnes, the average annual load of Road-related sediment input to the Río San Juan is, according to Dr Kondolf, 157 180 to 182 030 t yr^{-1}.

62. For comparison, the Costa Rican technical team estimates the rate of input of Road-related sediment to be 60 800 t yr^{-1}, based on their measurements which are described as reported in **Attachment CR-1 and CR-2**.

63. ICE monitor sediment transport at multiple gauging stations within the basin of the Río San Juan, including the Delta Colorado (Station 691104) on the Río Colorado immediately downstream of the Delta (see Figure 1). According to their records, and as explained in the ICE Report, the average annual total sediment load (that is suspended load plus bed load) carried by the Río San Juan between December 2010 and June 2013 was around 9 133 000 t yr^{-1}. In the ICE Report, it is estimated that at the Delta, 8 470 000 t yr^{-1} pass to the Río Colorado and 663 000 t yr^{-1} to the lower Río San Juan.

5.5.4 Input of Road-derived sediment to the Río San Juan

64. The sediment derived from erosion related to the Road as estimated by Dr Kondolf, makes up 1 or 2% of the total sediment load carried by the Río San Juan which is obviously too small a proportion to have an significant impact on the River.

65. Assuming that 10% of the additional sediment enters the lower Río San Juan suggests that the average annual input of Road-derived sediment to the lower Río San Juan is 15 718 to 18 203 t y^{-1}, which constitutes 2 or 3% of the total load in the lower Río San Juan downstream of the Delta.

5.5.5 Potential impact on sedimentation in the lower Río San Juan

66. The lower Río San Juan is approximately 30 km long and it has an average channel width around 90 m, giving it a bed area of about 2.7 million m^2. Using Dr Kondolf's estimate of sediment delivery to the Río San Juan (87 000 to 109 000 m^3y^{-1}), conservatively assuming that 10% of this enters the lower Río San Juan (8 700 to 10 900 m^3y^{-1}), and supposing that <u>all</u> of the Road-related sediment were deposited on the bed of the lower Río San Juan (with none at all deposited on the floodplains and in the wetlands or passing through to the Caribbean Sea, which is extremely conservative), the average increase in the rate of aggradation of the bed would be 3 to 4 mm y^{-1}.

67. It is immediately obvious that the addition of even the quantity of additional Road-derived sediment estimated by Dr Kondolf to the total annual sediment load of the lower Río San Juan could not have impeded navigation or required Nicaragua to take

active efforts, including dredging, to maintain the capacity and quantity of the River's waters.

5.5.6 Inputs of Road-derived sediment are not just insignificant, they are undetectable

68. It should be recalled that the annual load of the Río San Juan is not constant year-on-year but is different every year because it responds to natural variability in rainfall, runoff, erosion and channel evolution.

69. As reported in Section 5.2 above, monitoring of suspended sediment load in the Río Colorado immediately downstream of the Delta between 2010 and 2012 revealed that while the average annual load of suspended sediment was 5 981 000 t y^{-1}, the 95% confidence interval on the average value was between 5 181 000 and 10 585 000 t y^{-1} due to uncertainty and natural variability in the measured data. This means that there is a 95% probability that the suspended load carried in any year will be between 5 181 000 and 10 585 000 t, but there is a 5% chance that it could be still higher or lower than this. Variability in annual bedload is unknown, but is likely to be similar or greater than that in the suspended sediment load. It follows that using variability in suspended load to represent that in total load (i.e. suspended sediment plus bed loads) is conservative.

70. Observed variability in suspended loads indicates that the annual total sediment load of the Río Colorado will be within about +/- 20% of the mean value 95% of the time.

71. As around 90% of the discharge in the Río San Juan passes to the Río Colorado, it follows that the 95% confidence interval on the mean annual sediment load of Río San Juan must also be around +/- 20%. Similarly, as 100% of the discharge passing through the lower Río San Juan comes from the Río San Juan, the 95% confidence interval on its annual sediment loads is also likely to be about +/- 20%.

72. The increase of 1 or 2% predicted based on Dr Kondolf's estimated range for delivery of road-derived sediment to the Río San Juan falls well within the range of natural variability of sediment loads in the River represented by a confidence interval of

+/- 20%, meaning that even if such a change in load were to occur it would be indiscernible and statistically undetectable in records of measured loads.

73. The bed of the lower Río San Juan is formed in mobile sand, self-organised into ripples and dunes with amplitudes ranging from centimetres up to a metre or more, respectively. The bed also features pools and bars that cause in-channel depths to vary from several metres to a metre or less. It follows that a change in the rate of sedimentation by 3 or 4 mm y^{-1} (which is one and a half to two times the diameter of a single sand grain) would be imperceptible in the field and immeasurable using even high precision sonar equipment.

6. Response to new evidence submitted by Nicaragua

74. As mentioned in paragraph 8 above, I have been asked to review and comment upon the opinions expressed in Annex 1, Annex 2 and Appendix A submitted to the Court by Nicaragua on 1 November 2013.

75. At the outset, I note that the material dealt with in Annex 1 is largely repeated in Annex 2. Annex 1 records observations from a site visit in May 2013. Those same observations are repeated and elaborated in Annex 2 at pages 9-12. Annex 1 also repeats the list of 'recommended urgent measures' which is set out in Kondolf's 2012 Report and which are listed in the Request. For these reasons, I will focus my responses on the material contained in Annex 2.

76. On page of Annex 2 (paragraph two), it is reported that in May 2013 Dr Kondolf '*documented multiple "deltas" of sediment eroded from the road, and carried by local streams or newly eroded gullies into the river.*' Having examined the photographs in Appendix A, I am unsure of the basis on which Dr Kondolf can be so certain that all of the deltas documented in the photographs were composed entirely or even predominantly of '*sediment eroded from the road*'. My doubts stem partly from the fact is that the Road is not even visible in many of the photographs and there are certainly plenty of other potential sources of sediment on the Costa Rican side of the River; some natural, others anthropogenic but unrelated to the Road in either case. But there is a much more compelling reason for me to question

the causal link between the Road and the deltas that is made so easily in Annex and Appendix A. As noted in paragraph 10 above, I also participated in an overflight of the Road in May 2013, and I also noticed multiple deltas of sediment. However, many of the deltas I noticed were along the bank line of the Río San Juan on the Nicaraguan side. Several of them appeared quite a lot larger and considerably more prominent than those documented in Appendix A (Figures 8-10 show some examples). These deltas are composed of sediment eroded from Nicaraguan territory and deposited in the Río San Juan by Nicaraguan tributaries. They cannot be *deltas of sediment eroded from the Road.*

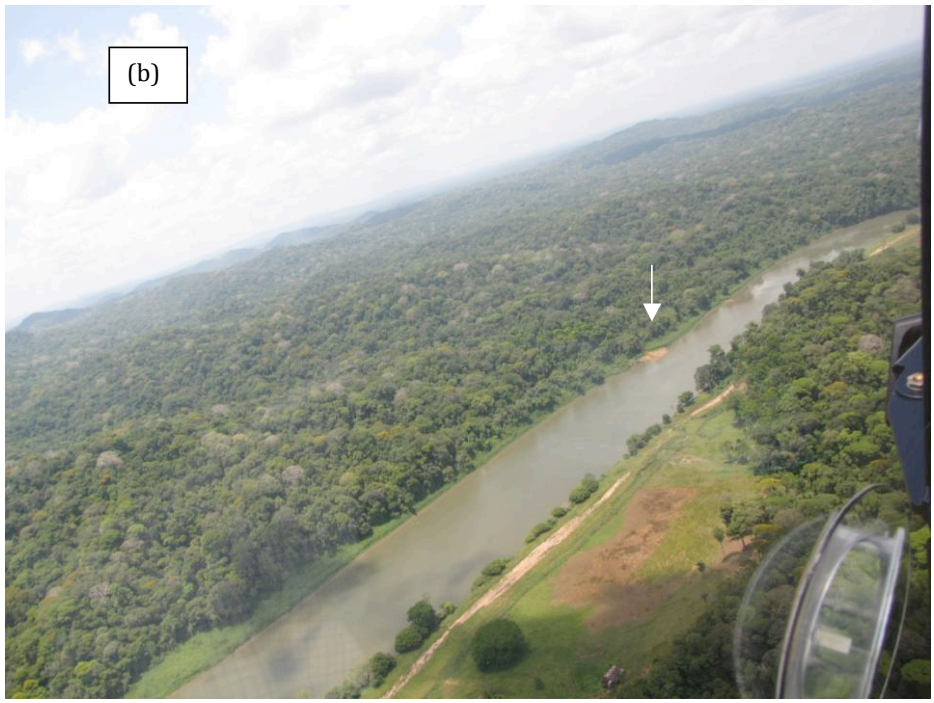


Figure 8. Prominent sediment delta observed in the Río San Juan from a helicopter in Costa Rican airspace on 7 May 2013 (a) close up and (b) wide angle view showing clearly that this delta is on the left (Nicaraguan) bank of the River. Route 1856 is clearly visible on the right (Costa Rican) side of the River (both photographs by author).

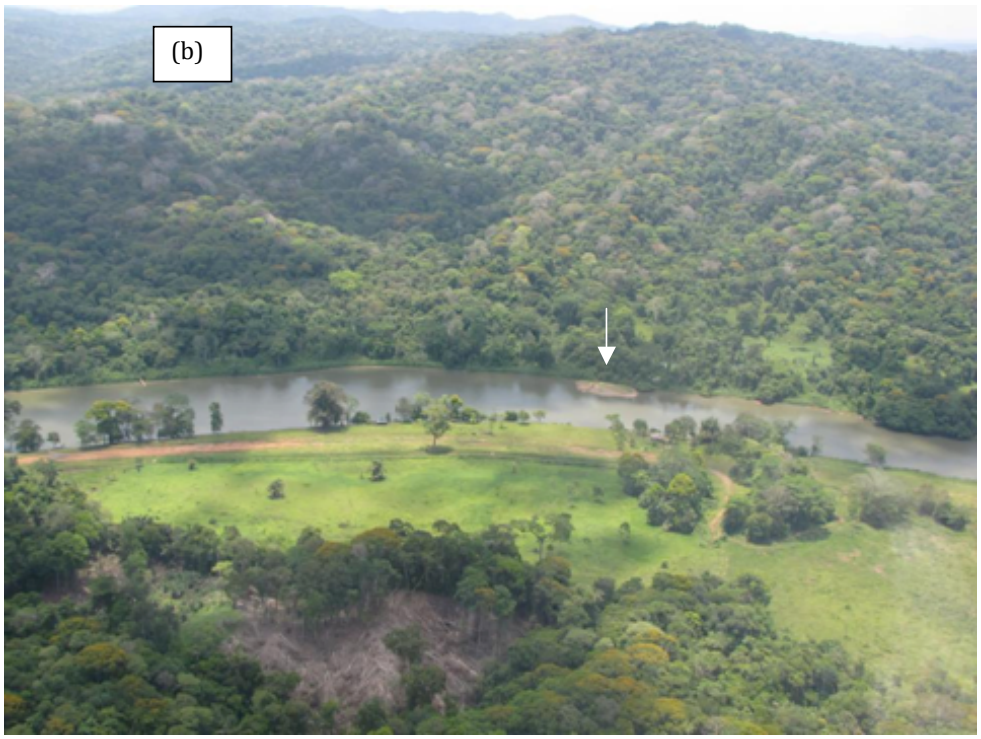


Figure 9. Large sediment delta observed in the Río San Juan from a helicopter in Costa Rican airspace on 7 May 2013 (a) close up and (b) wide angle view showing clearly that this delta is also on the far (Nicaraguan) bank of the River. Route 1856 is clearly visible on the near (Costa Rican) side of the River (both photographs by author).

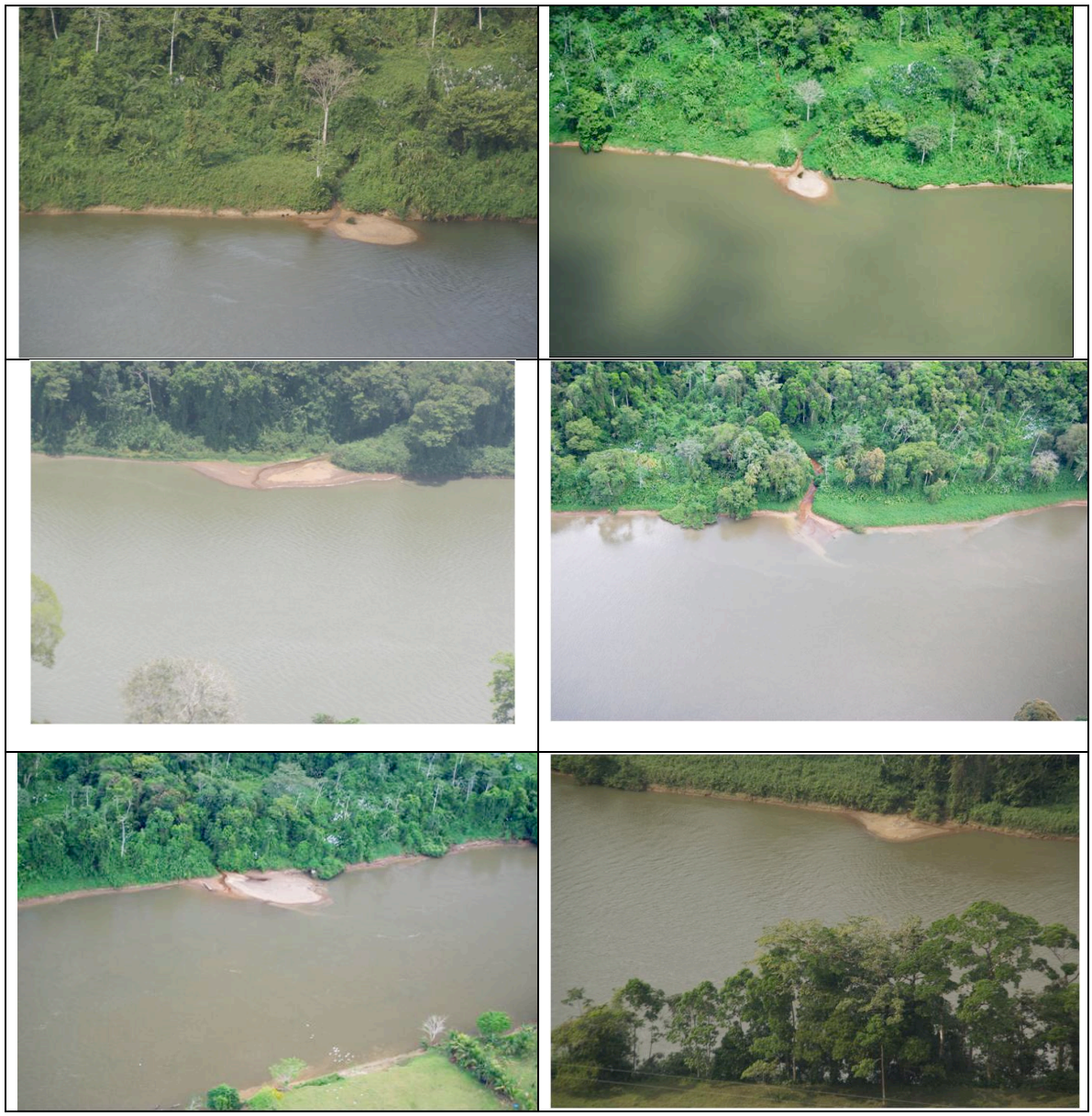


Figure 10. Photographs taken from Costa Rican air space on 7 May 2013. These show that deltas of sediment occur at most of the left bank tributaries of the Río San Juan. The deltas are unrelated to the Road and are formed by sediment delivered to the Río San Juan by streams drain catchments entirely within Nicaraguan territory.

77. I do not agree with the view that that sediment deltas in the Río San Juan are exclusively or perhaps even predominantly caused by deposition of sediment eroded from the Road. On the contrary, deltas are part of the natural sediment transfer system. They form when local rainstorms produce sediment-laden runoff from

tributaries, the coarse fraction of which is deposited in the lower course of the tributary channel and around the tributary confluence with Río San Juan. As Dr Kondolf notes, that deposition is temporary – deltaic sediments are re-eroded and transported downstream, diffusing into the receiving river's sediment load during the next significant sediment transport event in the main river. The limited size and wide spacing of the tributary deltas I observed in the Río San Juan in May 2013 means that they do not harm the River. Indeed, to the contrary, tributary bars and deltas are beneficial to the aquatic and riparian ecosystems because, for example, they provide fresh habitats and open niches for pioneer plant species – for example, as illustrated in photographs 1018, 1043 and 1046 in Appendix A.

78. In reviewing the impacts of road construction in rivers other than the Río San Juan, Annex 2 makes reference on page 7 (paragraph 2) to ecological impacts that stem from '*The combination of hydrological effects and increased erosion and sedimentation from road construction that result in significant increases of sediment loading to rivers and streams, which in turn, have been documented to cause a range of serious environmental problems*'. And in paragraph 5 on page 7, '*The delivery of massive volumes of sediment to rivers has resulted in significant ecological damage'*. These statements are entirely general in their terms and are only relevant to road construction that delivers increases in sediment loading that may justifiably be described as *massive* or at the very least *significant*. As explained in Section 5 above, even if we accept Dr Kondolf's upper bound estimate that 109 000 m^3 y^{-1} of sediment eroded from the Road has been delivered to the Río San Juan (an estimate which I believe to be too high by a factor of 3, and which incorporates all sediment input to the River considered significant in the 2012 Kondolf Report, and which is restated in Annex 2), this contributes about 2% to the sediment load carried annually by the Río San Juan. In no sense can such an increase be described as massive or even significant. Considering uncertainty in the sediment load associated with natural variability in the annual load such an increase is not only negligible, it is indiscernible.

79. On page 8 (paragraph 3) Dr Kondolf alludes to the finding reported by Reid and Dunne (2003) that '*road-related sediment can dominate the sediment budget in many rivers*'. As a general proposition and in the abstract, I agree with this

statement. But Reid and Dunne were not referring to the Río San Juan. In **Attachment CR-1**, ICE have constructed a sediment budget specific to this River: the Río San Juan. The result is depicted in Figure 11 (reproduced from **Attachment CR-1**), which illustrates that the contribution of road-related sediment is tiny in the context of this River. Road-related sediment may dominate the sediment budget in many rivers, but the Río San Juan is not one of them.

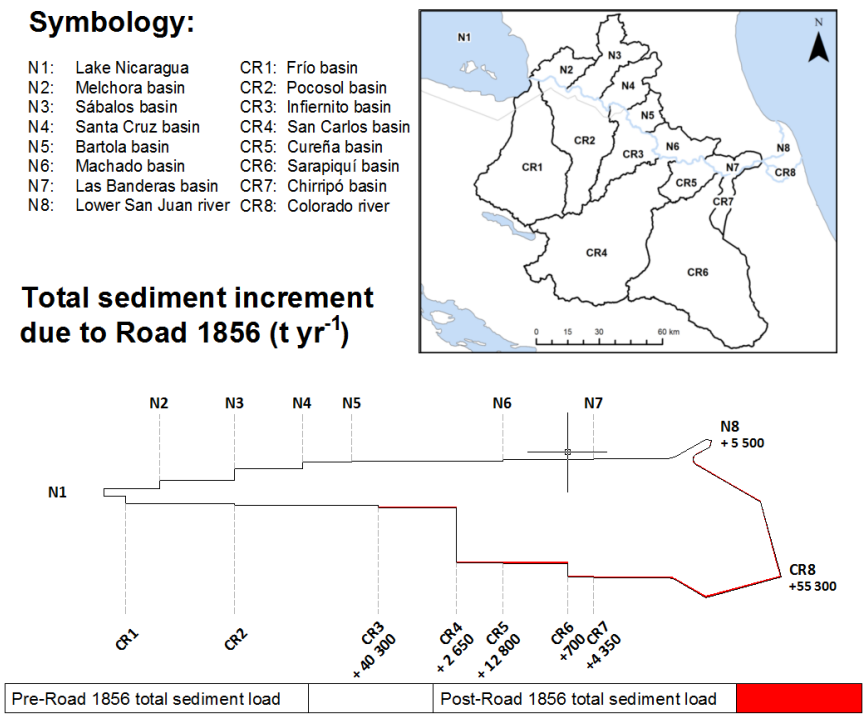


Figure 11. Increases in average annual sediment loads input to the San Juan – Colorado River system due to construction of Route 1856 are illustrated by the red lines in this version of the sediment balance diagram. Inputs of road-derived sediment are specified numerically: for example, the largest change in average annual sediment load input to the San Juan River is +40 300 t y^{-1} from CR5 (the Infiernito Basin). The narrow width of the red band is correctly scaled and accurately portrays that cumulative sediment inputs from Route 1856 are so small relative to pre-construction loads that they are not only difficult to see but inconsequential and practically undetectable (from Attachment CR-1 – the ICE Report).

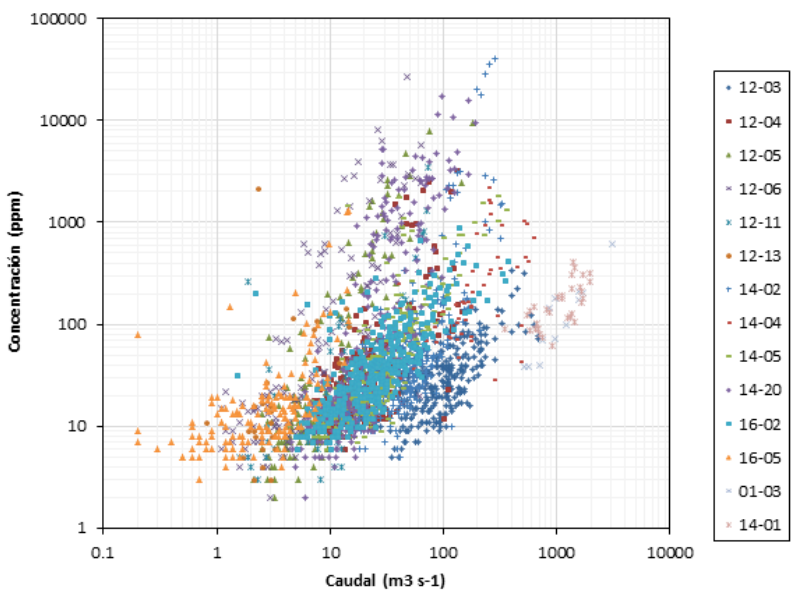
80. On page 11 (paragraph 2) of Annex 2, Dr Kondolf reports suspended sediment concentrations in three samples of muddy-water in plumes in the River, which had entered the River following a 15 minute downpour. The samples had SSCs of 364, 459 and 483 grams per cubic metre. Dr Kondolf describes these SSCs as '*high*'. He also took two samples of River water, both of which had SSCs of 8 grams per cubic metre. In **Attachment CR-1**, ICE report not five SSC samples, but 2,409. Table 6

(reproduced from **Attachment CR-1**) lists the sources of SSC data for the Rio San Juan and its Costa Rican tributaries and these data shown graphically in Figure 12. The full results may be found in Appendix A of **Attachment CR-1**.

Table 6. Properties of the sediment gauging stations in the Costa Rican basins draining to the San Juan River (from Attachment CR-1, the ICE Report).

Station code	Station name	Basin	River	No. of samples	Sampling period	SSL (t yr^{-1})	SY (t ha^{-1} yr^{-1})
01-03	La Trinidad	San Juan	San Juan	12	1974-1976	7 995 000	1.92
11-04	Delta Colorado	San Juan	Colorado	31	2010-2013	5 981 000[a]	-
12-03	Puerto Viejo	Sarapiquí	Sarapiquí	264	1970-1998	165 500	1.96
12-04	Veracruz	Sarapiquí	Toro	285	1972-2012	101 000	5.29
12-05	Bajos del Toro	Sarapiquí	Toro	137	1985-2001	50 000	6.85
12-06	Toro	Sarapiquí	Toro	117	1995-2010	20 500	5.00
12-11	San Miguel	Sarapiquí	Volcán	47	1998-2010	23 000	3.90
12-13	Río Segundo	Sarapiquí	Segundo	25	1999-2009	1 800	1.06
14-02	Jabillos	San Carlos	San Carlos	338	1967-2011	600 000	10.9
14-04	Terrón Colorado	San Carlos	San Carlos	53	1998-2009	1 300 000	8.35
14-05	Peñas Blancas	San Carlos	Peñas Blancas	308	1970-2011	157 000	5.36
14-20	Pocosol	San Carlos	Peñas Blancas	278	1980-2012	358 000	28.9
16-02	Guatuso	Frío	Frío	361	1970-2012	60 800	2.40
16-05	Santa Lucía	Frío	Venado	153	1984-2011	8 100	2.38

Note: SSL = suspended sediment load; SY = specific yield.
[a]This value is measured at the Colorado River. Hence, it is not directly comparable to the SS load at La Trinidad station (01-03).



Note: 1 gram per cubic metre = 1 part per million (ppm)

Figure 12. Suspended sediment concentration as a function of discharge for 2 409 samples taken from the Río San Juan and Costa Rican tributaries. Note: Station 14-01 in the legend refers to Delta Colorado (Station 11-04) in Table 6 (from Attachment CR-1, the ICE Report).

81. The SSCs measured in this larger data set vary from less than 10 ppm (or grams per cubic metre – the two measures of SSC are equivalent) to more than 10 000 ppm. While the background SSC in the River as measured by Dr Kondolf was indeed low, the concentrations in the plume of muddy-water are not high in the context of SSC's routinely observed in runoff draining to the Río San Juan, or even in the River itself. I am not surprised that a 15-minute rainstorm in May produced a striking contrast between SSCs in local runoff and the receiving water because under these circumstances the source of sediment is localised to the area of the rainstorm while discharge and background SSCs in the River are at their lowest. However, the volume of muddy water is a tiny fraction of even the lowest discharge in the Río San Juan and turbulent mixing would ensure that the *relatively high* SSC decreases to background levels within a short distance downstream and a short time after the rainstorm ends, as the plume of local runoff diffuses into the far greater flow in the receiving water.

82. With two exceptions, Annex 2 adopts a descriptive approach in presenting a literature review of the impacts of road building on rivers other than the Río San Juan (much of which is similar or even identical to material presented previously in the 2012 Kondolf Report), together with textual commentary and a virtual tour of the case in point, both of which extend only to 41 km of the Road between Marker II and the Rio Infiernito. The five suspended sediment samples constitute one exception to this approach. The other exception is the reported results of Dr Rios' sampling of the periphyton at nine sites, in late May 2013. On page 13 (paragraph 1) Annex 2 makes clear that four samples came from the deltas assumed by Dr Kondolf to be composed of sediment eroded from the Road on the south (Costa Rican) bank of the River. The text is less clear concerning the nature of the sample sites on the north (Nicaraguan) bank. We are told these were, 'five sites draining relatively undisturbed landscapes'. What we are not told is whether those sites were on any of the multiple deltas I observed at the Nicaraguan side of the River earlier that month. If they were then it would be a fair to compare them; if they were not then the comparison between samples taken at the north and south banks is inapt.

83. Putting the evidence together, I can find nothing to support the statement made in paragraph 4 on page 2 of Annex 2 that Dr Kondolf and his team '*already see extensive, severe environmental damage*'. As regards the case in point, irreversible damage to the Rio San Juan, this statement seems at odds with the photographs in Annex A, let alone the evidence provided in this report, which is supported by data provided in **Attachments CR-1 and CR-2**. In the same paragraph, the statement that, 'There is no question that when intense rains associated with tropical storms and hurricanes occur, the damage will be widespread and severe.' Indeed, it would. The scale at which such events cause damage simply dwarfs that of the Road. For example, in 1998 Hurricane Mitch is reported to have destroyed not 41 but 1300 km of road in Costa Rica alone, though not in the region of the Rio San Juan. The fact is that if this region were to suffer a tropical storm or a hurricane not only would this be devastating, it would also be unprecedented. In the circumstances that this particular region has never been hit by a hurricane or tropical storm (as to which see the United States National Oceanic and Atmospheric Administration (NOAA) map which is provided as **Attachment CR-8**, which indicates that no hurricane or tropical storm has been recorded in the area to date), it cannot be said that there is any serious or imminent risk of the kind of damage such an event would inflict upon the region. In the concluding part of paragraph 4 on page 2 of Annex 2, Dr Kondolf makes reference to irreversible harm done to salmon by massive mining in California and extensive logging in the Pacific Northwest. This contrasts with statements in the 2012 Kondolf Report that attribute the demise of pacific salmon populations in the USA to road building alone, which was not the case. But there are no salmon in the Rio San Juan and in any case construction of a Road that increases the impermeable area in the Costa Rican basins draining to the Rio San Juan by 0.05% cannot be compared to the catchment-wide practices of hydraulic mining and clear-cut forestry that occurred in California and the Pacific Northwest.

7. My observations of mitigation works on the Road in May 2013

84. During my first visit to the Route 1856 in February 2013, I inspected mitigation works under construction at several points along the Road between Marker II and the Río Infiernito, including speaking to senior engineers from Conservando Mejorando y

Construyendo la Red Vial Nacional - CONAVI (http://www.conavi.go.cr/). An engineer from the lead contractor MECO (http://constructorameco.com) was present, as was an engineer with the contractor responsible for materials Durman (http://www.durman.com/inicio.htm).

85. During my second visit to the Road in May 2013, I focused particularly on the 41.6 km stretch between Marker II and Boca San Carlos including inspection of mitigation works performed since my February visit. I did so based on the focus on this stretch in the 2012 Kondolf Report, my own observations of eroding cut and fill slopes in this stretch in February 2013, and my conclusion that there were very few eroding slopes along the Road between Boca San Carlos and the Delta. I was accompanied in the field by Mr Carlos Pereira who was at that time leading the mitigation effort on behalf of CONAVI. I also took the opportunity to inspect some of the sites proposed for erosion monitoring by the University of Costa Rica (see the UCR Report for a full account).

86. Before and after photographs of a representative selection of the mitigation sites I visited are included below in Figures 13-18.

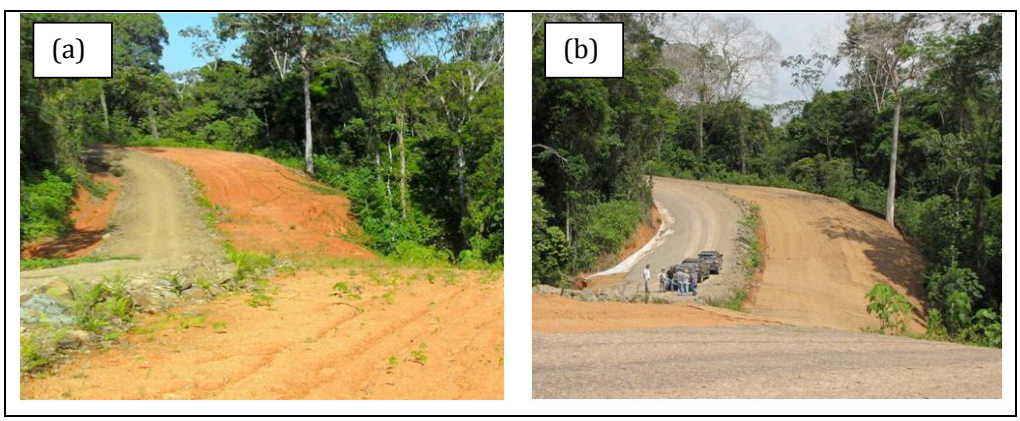


Figure 13. The Road near Marker II (a) prior to mitigation work on 15 February 2013 and (b) on 7 May 2013 with mitigation measures in place: note in-board drainage channel and extensive biodegradable, erosion control matting. Photographs by author.

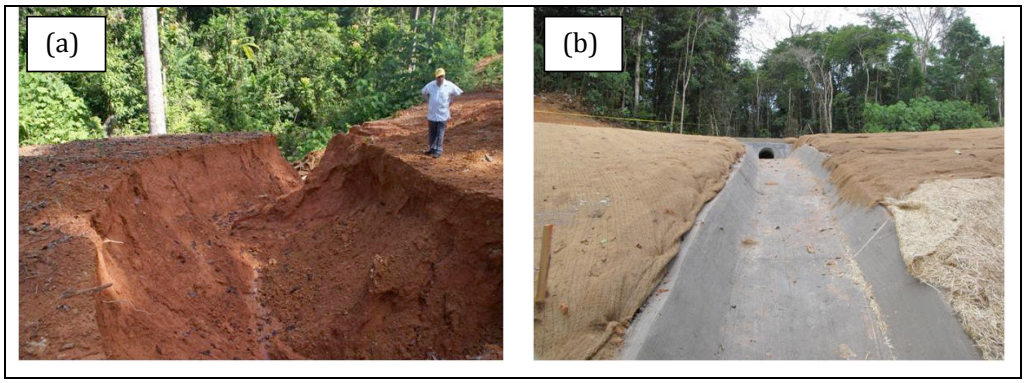


Figure 14. View down a large gully in a fill prism created by concentrated runoff from the Road draining to Costa Rican territory to the west of Marker II (a) in February when it was actively eroding and (b) in May when the gully had been back-filled and stabilized using a culverted cross-drain and concrete drainage channel, with coconut matting used to protect the surrounding fill slope from sheet and rill erosion. Photographs by the author.

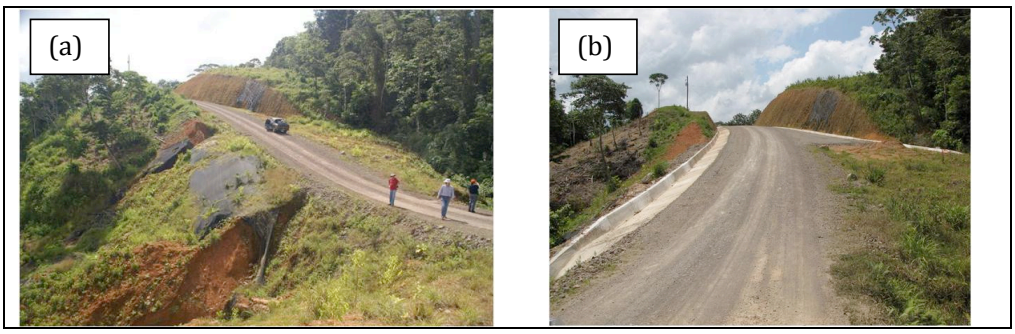


Figure 15. Road near Tiricias (a) on 15 February when failure of geotextile slope protection had allowed concentrated out-board runoff from the Road to create two gullies and in-board runoff was undercutting a cut slope (b) on 7 May 2013 after construction of concrete-lined out-board and in board ditches. Photographs by author.

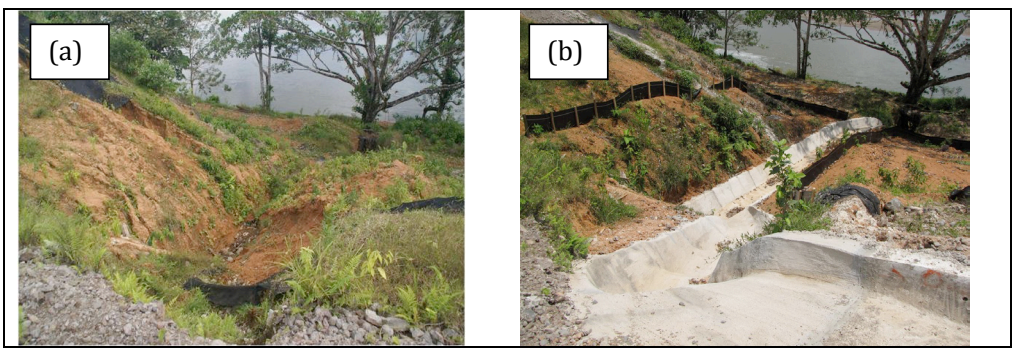


Figure 16. Road between Marker II and Río Infiernito (a) on 15 February 2013 showing network of gullies on outboard slope and sediment accumulated as a run-out deposit on flat terrace surface separating foot of slope from the bank of the Río San Juan (b) on 7 May 2013 showing mitigation works including concrete channels and drop structures to convey runoff from the road bed and silt fences to protect the slope from sheet and rill erosion and prevent road-derived sediment reaching the terrace. A sediment trap has also been constructed at the downstream termination of the gully system, though this cannot be easily identified in the photograph. Photographs by author.

Figure 17. Road near Río Infiernito (a) on 15 February when surface unmanaged runoff from the road bed and surrounding slopes disturbed during construction had caused sheet and rill erosion of bare soil surfaces. (b) same stretch of road on 7 May 2013 after protection of the road surface using crushed rock, installation of silt fences to prevent sheet and rill erosion while directing down-slope surface runoff into concrete-lined outboard and inboard ditches. Photographs by author.

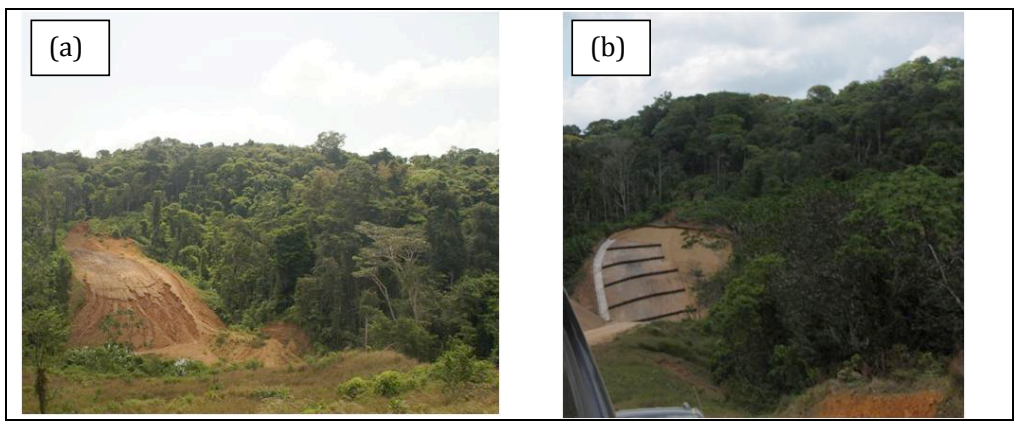


Figure 18. Road near Río Infiernito (a) on 15 February when unmanaged runoff from the path cleared in preparation for construction of the road bed had caused sheet and rill erosion. (b) The same area road on 7 May 2013 after installation integrated measures to manage runoff involving regrading, silt fences, and concrete-lined outboard ditch. Photographs by author.

87. Based on the observations of the Road on 15 February and 7 May 2013 that are reported above it may be concluded that, during the intervening period, substantial engineering works were performed by MECO (overseen by CONAVI) at multiple locations along the Road between Marker II and Boca San Carlos, of which those illustrated in Figures 13-18 are a representative sample. I also observed extensive areas of reforestation undertaken by local contractors.

88. I have also reviewed Consejo Nacional de Vialidad (CONAVI), Program for the Consolidation and Continued Improvement of Route No 1856,

Reference DIE-02-13-3107, 25 October 2013 (**Attachment CR-3**); Report from Ana Lorena Guevara Fernández, Vice-Minister of the Environment, Costa Rica, to Enrique Castillo Barrantes, Minister of Foreign Affairs, Costa Rica, Reference DVM-293-2013, 8 October 2013 (**Attachment CR-5**); and Comisión de Desarrollo Forestal de San Carlos (CODEFORSA), Consulting Services for the Development and Implementation of an Environmental Plan for the Juan Rafael Mora Porras Border Road, Report of Activities to the Ministry of Foreign Affairs of the Republic of Costa Rica, January 2013 (**Attachment CR-6**). These reports detail the continuing work to reduce any erosion risk presented by the Road. I do not agree with the recommendation in the opening sentence of paragraph 4 on page 2 of Annex 2 that, '*If work continues on Rte 1856, its impact will be devastating to areas directy affected and to downstream receiving waters*'. On the contrary, I believe that mitigating work should continue in order to minimise the risk of future erosion should heavier rainfall occur.

89. Based on my experience with engineered and biotechnical erosion mitigation works in other areas experiencing heavy rainfall, including Ethiopia, Bangladesh and the USA, my opinion is that the measures taken by Costa Rica have reduced and will continue to reduce the risk that significant erosion might occur during heavy rainstorms, compared to conditions immediately following construction of the Road. Consequently, I do not agree with the conclusion drawn in paragraph 3 on page 2 of Annex 2 that, '*erosion control and drainage works have been ineffective*'.

90. It is my understanding that the measures I observed in May 2013 are part of ongoing efforts intended to reduce erosion risks stemming from the way the Road was constructed in 2011 and that they are not intended to provide a permanent solution to erosion issues. Given that, my experience suggests that with appropriate inspection and, where necessary, maintenance or repair, the mitigation works will significantly reduce local erosion rates for the next year or two, allowing time for the work necessary to design, contract and build permanent works to progress.

8. Conclusions on the risk of irreversible harm to the River

91. There is no scientific justification for '*active efforts, including dredging, to maintain the capacity and quantity of the river's waters*' in the lower Río San Juan on the

pretext of having to remove Road-derived sediment. Sediment transfer and deposition calculations based on measured data and conservative assumptions demonstrate that, even using the range of sediment contributions by the Road to the River given in the 2012 Kondolf Report (which are almost certainly too high by a factor of 2 to 3, and which incorporate all sediment input, including from mass wasting), the additional amount of Road-derived sediment entering the lower Río San Juan is probably just 2% or 3% of its total load. Sediment continuity dictates that even if all of this sediment were to be deposited on the bed of the channel, it would raise the bed of the river by only 3 or 4 mm per year. In fact, deposition is spread over a much wider area of floodplain, wetlands and wash lands and an unknown but significant percentage of the load is discharged to the Caribbean Sea. Hence the estimates of increase sediment load and bed deposition are necessarily over-estimates. They are in any case well within the error margin for sediment measurements and calculations, and are small in comparison to inter-annual fluctuations that are the product of natural variability.

92. Similar investigations and calculations could be performed with respect to the other potential impacts of the Road on the Río San Juan mentioned in the Request. In summary, due to very small relative contribution of sediment in comparison to the heavy and highly variable sediment load in this River, the Road cannot possibly pose a risk of imminent, irreversible harm to the morphology, environment, or ecology, all of which are well-adapted to the heavy load and highly variable sediment regime of the Río San Juan.

9. References

ICE (Costa Rican Institute of Electricity) 2013. *Report on hydrology and sediments for the Costa Rican river basins draining to the San Juan River*. Federico Gómez Delgado, Juan José Leitón Montero and Carlos Aguilar Cabrera, Centre for Engineering Studies, Department of Hydrology, San José, Costa Rica (**Attachment CR-1**).

UCR (University of Costa Rica) 2013. *Systematic Field monitoring of Erosion and Sediment Yield along Route 1856*. Rafael Oreamuno Vega, M. Eng. and Roberto

Villalobos Herrera, Universidad De Costa Rica, Facultad De Ingeniería, Escuela De Ingeniería Civil (**Attachment CR-2**).

10. Statement of independence and truth

93. The opinions I have expressed in this Report represent my true and complete professional opinion. Where I have relied on information or facts supplied to me by those instructing me, I have noted this in my Report.

94. I understand that my overriding duty is to the Court, both in preparing this Report and in giving oral evidence, if required. I have complied and will continue to comply with that duty.

95. I have set out in my Report what I understand from those instructing me to be the questions in respect of which my opinion as an expert is required. I have done my best, in preparing this Report, to be accurate and complete. I have mentioned all matters that I regard as relevant to the opinions that I have expressed. I consider that all the matters on which I have expressed an opinion are within my field of expertise. I have drawn the attention of the Court to all matters, of which I am aware, which might adversely affect my opinion.

96. In preparing this Report, I am not aware of any conflict of interest actual or potential which might impact upon my ability to provide an independent expert opinion. I confirm that I have not entered into any arrangement where the amount or payment of my fees is in any way dependent on the outcome of this proceeding.

97. I have not, without forming an independent view, included anything which has been suggested to me by others, including those instructing me.

98. At the time of signing this Report I consider it to be complete and accurate assessment of the information available to me, subject to any qualifications noted herein. I will notify those instructing me if, for any reason, I subsequently consider that the Report requires any material correction or qualification.

99. I understand that this Report will be the evidence that I will give, if required, under oath, subject to any correction or qualification I may make before swearing to its veracity.

100. The substance of all facts and instructions given to me which are material to the opinions expressed in this Report or upon which those opinions are based are reflected in my Report.

101. I confirm that I have made clear which facts and matters referred to in this Report are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. The opinions I have expressed represent my true and complete professional opinion.

……

Professor Colin Thorne
2 Parker Gardens
Nottingham, UK
4 November 2013

ANNEX 10

Costa Rica, Centro Científico Tropical

Environmental Diagnostic Assessment (EDA), Route 1856 Project – Ecological Component

November 2013

Environmental Diagnostic Assessment

Ecological Component

Project Route 1856 "Juan Mora Porras"

CENTRO CIENTIFICO TROPICAL

San José, Costa Rica.
November, 2013.

Contacts

Tel: (506) 2253-3267
Fax: (506) 2253-4963
Oscar Lücke Sánchez, MSc.
olucke@cct.or.cr
Olivier Chassot Labastrou, Ph.D.
ochassot@cct.or.cr

i. Acknowledgments

Acknowledgements are extended to Oscar Lücke and Biologist Raquel Gomez for their collaboration throughout the length of this study. Likewise to Jorge Mairena and Biologist Fatima Reyes for the invaluable assistance and collaboration during the extent of the project. Thanks to Monika Springer (University of Costa Rica) for the use of the sampling equipment and tools of the aquatic bio-monitoring laboratory, AquaBiolab S.A.

Acknowledgements are also extended to the work team of the Basic Studies Department of the Costa Rican Electrical Institute, to the Hydrology Department of the University of Costa Rica, to the National Conservation Areas System and to the National Highways Council for information provided on the area where the project is located.

Thanks to Freddy Rodríguez, Ulises Aleman, Sergio Balladares, Rafael Orozco, Edwin Leitón and Fidel Gonzales; to Aero Diva, Maquenque Ecolodge, Laguna Lagarto Lodge, El Manzano Hotel, Delta Cabins and the Office of National Security for their assistance with fieldwork.

Finally, grateful recognition to Laura Mairena, Roger Zelaya, and all members of the Tropical Science staff, for their support with the logistic, administrative and financial coordination of the project.

ii. Professional team, Ecological Component, EDA- Route 1856 Project.

This document was coordinated and prepared by the TROPICAL SCIENCE CENTER, with the participation of the following professional specialists:

Professional Specialist	Field	Professional Association, SETENA membership	Signature
Oscar Lücke Sánchez, MSc.	Geography Technical Coordinator	Colegio: CIA-6450 SETENA: CI-235-12	_____
Olivier Chassot Labastrou, Ph.D.	Natural Sciences for Development and Environmental Management Technical Coordinator	Colegio: 1967 SETENA: CI-157-12	_____
Ana Luisa Báez Rojas	Sustainable Tourism	Colegio: 1202	_____
Guisselle Monge Arias, Ph.D.	Biology and Natural Resources Management	Colegio: 844 SETENA: CI-146-13	_____
Rafael Bolaños Montero	Forestry and Land Use	Colegio: CIA-4377 SETENA: CI-001-98	_____
Bernald Pacheco Cháves	Aquatic Biology	Colegio: 1695 SETENA: CI-214-08	_____
Andreas Mende, Ph.D.	Digital Cartography and Geographic Information Systems		_____

iii. Table of Contents

1 EXECUTIVE SUMMARY 13
2 INTRODUCTION 15
2.1 Background 15
2.2 Scope of Study 15
2.3 Objetives 16
2.3.1 General Objective 16
2.3.2 Specific Objectives 16
2.4 Methodology 16
2.5 Time frame for the Ecological Component of the EDA 18
2.6 Terms of Reference 18
2.7 Limitations 19
3 PROJECT DESCRIPTION 20
3.1 Geographic Location 20
3.2 Political and Administrative Location 20
3.3 Estimated Project Area and Influence Areas 20
3.4 General Description of the Activity 22
3.5 Environmental Aspects 23
3.6 Environmental Risk Control System 30
3.6.1 Risk of Cutting Down Trees which are in Danger of Extinction 30
3.6.2 Risk of Slope Erosion and Slope Instability 30
3.6.3 Risk of Altering Natural Drainage Systems 30
3.6.4 Risk of Obstructing Waterways 30
3.6.5 Risk of Eroded Sediments Depositing on Bodies of Water 31
4 DESCRIPTION OF THE PHYSICAL ENVIRONMENT 32
4.1 Geology of the Study Area 32
4.1.1 Regional Tectonic Framework 32
4.1.2 Regional Geology 32
4.1.2.1 Ophiolites of Tiricias 33
4.1.2.2 Sarapiquí Arch 33
4.1.2.3 Quaternary Deposits 33
4.1.3 Seismic Activity 33

4.2 Geomorphology 34
4.2.1 Morphologies of Tertiary Vulcanism of the Extreme North of Costa Rica (Bergoeing et al., 1997) 34
4.2.2 Morphologies of Alluvial Quaternary Cones in Northern Costa Rica (Bergoeing et al., 1997) 34
4.2.3 Sedimentary Quaternary Morphologies 34
4.3 Soils 35
4.4 Climate 35
4.4.1 Micro-climates 35
4.4.2 Rainfall 36
4.4.3 Temperature 36
4.4.4 Solar Brightness 36
4.4.5 Dry Months 36
4.5 Hydrology/ Hydrography 36
5 DESCRIPTION OF THE BIOLOGICAL ENVIRONMENT 38
5.1 Introduction 38
5.1.1 Terrestrial Environment 39
5.1.1.1 Protection Status (Protected Areas) 39
5.1.1.2 Life Zones 42
5.1.1.3 Natural Associations and Land Cover 44
5.1.1.4 Current Plant Cover by Natural Association 46
5.1.1.5 Indicator species by natural ecosystem 58
5.1.1.6 Endemic species with reduced or threatened populations. 59
5.1.1.7 Fragility of Terrestrial Ecosystems. 65
5.1.1.8 Impacted flora species 68
5.1.2 Aquatic Environment (inland water bodies). 68
5.1.2.1 Aquatic Fauna 74
5.1.2.2 Characterization of the Riparian System. 87
5.1.2.3 Indicator Species. 87
5.1.2.4 Endemic Species with Reduced or Threatened Populations 106
5.1.2.5 Fragility of the Inland Aquatic Environment. 109
6 ENVIRONMENTAL DIAGNOSTIC 113
6.1 Comprehensive environmental susceptibility map vs.Project components. 113
6.2 Identification of impacts and environmental risks 131

6.2.1 Activities susceptible of causingenvironmental impacts 131
6.2.2 Impacted or potentially impacted environmental factors 131
6.2.3 Identificationof environmental impacts 131
6.2.4 Description of identified Environmental impacts 132
6.2.4.1 Terrestrial flora and fauna 132
6.2.4.2 Aquatic flora y fauna 134
6.2.4.3 Landscape 134
6.3 Assessment of Environmental impacts and corective measures 135
6.3.1 Methodology 135
6.3.2 Impact Assessment 139
6.4 Risk analysis and contingency plans 141
6.4.1 Sources of environmental risk 141
6.4.2 Environmental risk evaluation 143
6.5 Environmental control measures 144
6.5.1 Environmental control measures for the identified impacts 144
6.5.1.1 Control measures for terrestrial flora and fauna 144
6.5.1.2 Aquatic flora and fauna 148
6.5.1.3 Paisaje 150
6.6 Environmental Management Plan – Environmental Adequacy Plan (PAA) 150
7 Conclusions y recommendations 156
7.1 Conclusions 156
7.1.1 Terrestrial Biology 156
7.1.2 Aquatic Biology 157
7.1.3 Tourism 159
7.1.4 Ecological Connectivity 160
7.2 Recommendations 161
8 REFERENCES 164
9 ANNEXES 170
9.1 BioSketches of consultants participating in the realization of the EDA-Ecological Component 170
9.1.1 Geography and Land Use Planning Expert 170
9.1.2 Sustainable Tourism Expert 171
9.1.3 Biology and Management of Natural Resources Expert 172
9.1.4 Land Use Expert 173

9.1.5 Aquatic Biology Expert 174

9.1.6 Geographic Information Systems Expert 175

9.1.7 Connectivity Expert 176

9.2 Impact assessment of the implementation of the Route 1856 project on the development of tourism activities in the San Juan River 177

9.3 Analysis of the structural connectivity in the landscape of Route 1856 203

9.4 Threatened species potentially found in the Border Biological Corridor Mixed Wildlife Refuge and Maquenque Mixed Wildlife Refuge. 225

9.5 Limited and threatened species to be used in local reforestation. 234

9.6 Tree species observed in the area of Las Crucitas, San Carlos. 236

9.7 Taxa richness and abundance of individuals of aquatic macroinvertebrates collected at study sites along Route 1856, Juan Rafael Mora Porras, July - August, 2013. Upstream (Abj) and downstream (Arb) of the road. (*) less common taxa or with limited distribution in the country. 242

Chart Index

Chart 1: Activities conducted during the Project construction stage. 23

Chart2: Hydrographic Watersheds in the Study Area 36

Chart3: Natural Associations recognized in the study area.. 48

Chart4: Area occupied by natural assocaitions recognized in the DIA. 55

Chart5: Common or outstanding tree species in palustrine or lacustrine wetlands. 56

Chart6: Common tree species in forest associations. 58

Chart7: Main threatened species within the Route 1856 study area. 62

Chart8: Endemic tree species reported for the study area. 63

Chart9: Tree species at risk. 64

Chart10: Species officially under ban. 65

Chart11: Variation in number of species and trees in condition different from forest (in the Biological Border Corridor) in 0,25 ha plots, for trees thicker than 10 cm DBH. 66

Chart12: Fragility of terrestrial ecosystems characterized for this study. 67

Chart13: Area impacted for each ecosystem within the project area. 68

Chart14: List of aquatic fauna recorded for the project area and surroundings. 74

Chart15: List of aquatic macroinvertebrate taxa for the project area and surroundings. 81

Chart16: Listof phytoplancton species recorded for the San Juan tributaries. 85

Chart17: Description of sites and sampling points along Route 1856. 90

Chart18: BMWP-CR' index values and water quality at sampled sites along Route 1856, 2013.99
Chart19: Water quality classification according to BMWP-CR Index. 100
Chart20: Species of aquatic fauna recorded for the project area included, included in some conservation category 106
Chart21: Modified matriz for impact identification related to Route 1856. 132
Chart22: Evaluation criteria for the MIIA. 136
Chart 23: Matrix of Importance of Environmental Impacts(MIIA) for the Route 1856project in Costa Rica territory. 140
Chart24: Matrix of Importance of Environmental Impacts (MIIA) for the Route 1856 project on Nicaraguan territory 142
Chart25: Environmental risk evaluation for the Route1856 project. 143
Chart26: Environmental Adequacy Plan (PAA). 152

Map Index

Map 1: Geographic Location of the Project 21
Map 2: Road Design Location (1 of 6). 24
Map 3: Road Design Location (2 of 6). 25
Map 4: Road Design Location (3 of 6). 26
Map 5: Road Design Location (4 of 6). 27
Map 6: Road Design Location (5 of 6). 28
Map 7: Road Design Location (6 of 6). 29
Map 8: Conservation Areas and Protected Areas. 41
Map 9: Life Zones 43
Map10: Map ofEcosystems (1 of 6). 49
Map11: Map of Ecosystems (2 of 6). 50
Map12: Map of Ecosystems (3 of 6). 51
Map13: Map of Ecosystems (4 of 6). 52
Map14: Map of Ecosystems (5 of 6). 53
Map15: Map of Ecosystems (6 of 6). 54
Map16: Location of Great Green Macaw nests. 61
Map17: Location of water bodies registered for the area of study (1 of 4). 70
Map18:Location of water bodies registered for the area of study (2 of 4). 71
Map19:Location of water bodies registered for the area of study (3 of 4). 72

Map 20:Location of water bodies registered for the area of study (4 of 4). 73

Map21: Location of sampled bodies of water with classification of water quality according to BMWP-CR' Index, along the study area of Route 1856. 101

Map 22: Location of sampled bodies of water with classification of water quality according to BMWP-CR' Index, along the study area of Route 1856. 102

Map23: Location of sampled bodies of water with classification of water quality according to BMWP-CR' Index, along the study area of Route 1856. 103

Map24: Environmental Diagnostic Section 1. 114

Map25: Environmental Diagnostic Section 2. 115

Map26: Environmental Diagnostic Section 3. 116

Map27: Environmental Diagnostic Section 4. 117

Map 28: Environmental Diagnostic Section 5. 118

Map29: Environmental Diagnostic Section 6. 119

Map 30: Environmental Diagnostic Section 7. 120

Map31: Environmental Diagnostic Section 8. 121

Map32Environmental Diagnostic Section 9. 122

Map33: Environmental Diagnostic Section 10. 123

Map34:Environmental Diagnostic Section 11. 124

Map35: Environmental Diagnostic Section 12. 125

Map36:Environmental Diagnostic Section 13. 126

Map37: Environmental Diagnostic Section 14. 127

Map38:Environmental Diagnostic Section 15. 128

Map 39: Environmental Diagnostic Section 16. 129

Map40: Environmental Diagnostic Section 17. 130

Glossary

Agarradores: "clingers", organisms found in bodies of water with strong currents, which often have adaptations (long, strong nails, hooks, suction cups) to hold on to the surroundings.

Auto-trophs: organisms that have the ability to synthesize all elements essential to their metabolic needs based on non-organic substances, such that they do not need other living organisms for their nourishment.

Bailey bridge: portable pre-fabricated metal bridge, designed primarily for military use, which is used in many countries as a provisional bridge while a permanent structure is being built.

Bentonic: relative to the community formed by organisms that inhabit the bottom of aquatic ecosystems; adjective: bentonic.

Bentonic macro-invertebrate: non-vertebrate animal that lives all or part of its life cycle in the bottom or in the substratum of the bottom layer found in bodies of fresh water, whose body size allows direct visual observation without the use of instruments.

Bio-indicator: organism selected for its degree of sensibility or tolerance to diverse types of contamination or its effects. It measures or quantifies the magnitude of stress and degree of ecological response to it.

Biological Corridor: a territory that offers connectivity among landscapes, eco-systems and habitats, natural or modified, assuring the presence of biological diversity and ecological processes.

Boundary marker or landmark: artificial structure used commonly to define the limits of properties and territories.

Branchiae: gills, respiratory organs of aquatic animals which allow extraction of oxygen diluted in the water, and transference of carbon dioxide (CO_2) to the environment.

Caudal: current, quantity of water that moves through a section of a river during a given unit of time.

Caño: channel, water course that runs through muddy, flooded terrain, or through palustrine or lacustrine wetlands, whose depth and appearance change as a function of the level of water.

"Climbers": organisms that live in the submerged part of aquatic plants.

Collectors: organisms that collect fine particles deposited in water surfaces.

Community: group of organisms of all species that co-exist in a defined space called a biotope which offers the required environmental conditions for their survival.

Density: number of organisms in an area or defined volume.

Detriment: slight or partial destruction of something

Detritus: residues, generally solid and permanent, that result from the decomposition of organic sources (vegetal and animal); dead matter.

Diversity: related to the number or richness of species, as well as the equality or relative abundance of individuals between speciae.

Divers: organisms that dive and swim to feed themselves; often they spend time holding on to submerged objects.

Egg-laying: fish, reptiles and amphibians release eggs to the environment.

Endemic Species: taxon that is limited to a reduced geographic area, not found in a natural state anywhere else in the world.

Epi-lithic: organism that develops on the surface of hard substrata.

Extinction: disappearance of all the individuals of a species or a taxonomic group; a species is extinguished when the last individual of the species dies.

Filters: organisms that feed off particulate, fine, and very fine organic matter in suspension, which are collected by the organism with the use of mouth brushes or silk nets.

Forest: natural vegetation of a forest ecosystem of an extension greater than 2 hectares.

Forested: a section covered by natural tree vegetation, with variable surfaces, whether smaller or larger than 2 hectares.

Fragmenters: organisms that chew large pieces of vascular plants to feed themselves.

Habitat: area where organisms live and grow in natural fashion.

Interstitial Space: space or crevice between two bodies or between parts of a body.

Lacustrine: that exists or develops in waters of little or no movement (Gomez 1984 in Kappelle 2008).

Lentic: System of stagnant continental waters with little movement and exchange; as an example, lakes formed by emerging waters, lakes, ponds, swamps and marshes (Mata and Quevedo 2005 in Kappelle, 2008).

Monitoring: systematic use of biological responses to evaluate changes in the environment for the purpose of implementing conservation and control programs.

Morbility: proportion of organisms that become sick in a site over a specified period of time.

Mortality: number of individuals within a population that die within a specified period of time.

Palustrine: referring to stagnant or slow moving shallow waters with emergent vegetation at least in 30% of the area (Gomez 1984, in Kappelle 2008).

Phytoplancton: group of aquatic organisms that are plankton auto-thropic, have photosynthetic capacity and live dispersed in water.

Plancton: group of organisms, mainly microscopic, that inhabit salty or fresh waters, whose movement is passive.

Population: group of organisms, or individuals of the same species that co-exist in a given space and time, and share certain biological properties which produce a high reproductive and ecological cohesion in the group.

Predators: herbivores and other organisms that feed on other organisms.

Richness: number of species that are part of a community.

River: natural course of water that flows continuously, has a defined stream, constant throughout the yearly cycle, that flows into the sea, a lake, or another river (in which case it is considered an affluent or tributary course).

"Scrapers": organisms that feed on peri-phyton algae and microbes that adhere to rocks and other substrata.

Sediment: solid accumulated material on the terrestrial surface (lithosphere) derived from the action of phenomena and processes that act on the atmosphere, hydrosphere and biosphere (winds, temperature variations, meteorological precipitations, circulation of surface or underground waters, displacement of masses of water in marine or lacustrine environments, chemical agents or the action of live organisms.

Slope: slanting surface, inclined surface of land or artificial inclined structure that is part of an engineering work.

Skaters: organisms that live in the aerial phase on the surface film of water and skate on this surface.

"**Sprawlers"**: organisms that live in habitats, or micro-habitats with less current and which crawl on the surface of the bottom substratum, on rocks, sediment, leaves and wood.

Swimmers: organisms that live in permanent submersion and are capable of swimming with movements such as those of fish; organisms spend time holding on to rocks, roots of aquatic plants and other submerged objects.

Taxa: plural of taxon (Latin).

Tributary: body of water, also called **affluent** that does not run its course to the sea, but empties into a river, at a point known as the confluence of both.

Trophic level: each one of the groups of species or organisms of an eco-system that coincide by the place they occupy in the system of energy and nutrients circulation, that is to say, those that occupy an equivalent place in the food chain.

Wetland: area covered with water generally containing natural and semi-natural vegetation and very often rich in diversity of organisms.

"Yolillal" patch or extension: basal tropical eco-system that generally grows close to the coasts and is frequently inundated, and is dominated by the palm known as "Yolillo" (Raphia taedigera) (Kappelle 2008).

Acronyms

RNVSMM: Refugio Nacional de Vida Silvestre Mixto Maquenque

DBH: Diameter at Breast Height (1.30 meters)

TSC: Tropical Science Center

BBC: Border Biological Corridor

ICE: Costa Rican Electrical Institute

IGN: National Geographic Institute.

RSJ: San Juan River, on the Costa Rica- Nicaragua border.

UCR: University of Costa Rica.

1 EXECUTIVE SUMMARY

The Ministry of Foreign Affairs of the Government of Costa Rica commissioned the services of the Tropical Science Center (TSC) to conduct an Environmental Diagnostic Assessment of the road project known as Route 1856, taking into account factors such as the TSC´s 15 years of work experience in the area, its knowledge of ecosystems and its international scientific reputation.

The Project consisted in the construction of a gravel road that starts in the locality of San Jeronimo near the town of Los Chiles and stretches all the way east to a site known as Delta Siete (better known locally as Delta Costa Rica). The Project has a length of 159,7 km. with 101,5 km. (63,6%) of this length being mostly access and connecting roads that have been present in the area for more than 30 years. The remaining 57,4 km. (35,9%) of the Route is a new road designed to connect those existing roads along the border between Costa Rica and Nicaragua in close proximity to the San Juan River.

The study was planned according to legal requirements for such a study under Costa Rican law, taking into account that these studies are the appropriate instrument for environmental assessment applied to works that have already been executed, in order to determine their environmental conditions and impact, and to define the necessary measures to achieve environmental harmony within a systematic normative framework.

The environmental implications of the Route are defined on the basis of technical scientific criteria through the application of a national legal instrument that supports the definition of public policies in the area of environmental intervention of the Project.

The methodology included an exhaustive review of other research conducted in the region by the TSC, as well as other work done by scientists and institutions with recognized prestige such as the public universities. Furthermore, field work was also conducted through five field visits of several days' duration and an observation flight over the project area. Information was obtained from the legally established protected areas in the region, along with data generated by the Great Green Macaw Project of the TSC, satellite images and aerial photographs, among other.

The Environmental Diagnostic Assessment was based on the legal requirements described in the "Technical Guide for Environmental Diagnostic Studies" formulated by the National Technical Environmental Service (SETENA) of the Ministry of the Environment (MINAE) through Resolution No. 2572-2009 of November 2, 2009. Four months were dedicated to the formulation of the study in its ecological component, a process that was recorded in detail in a video of the current conditions of the Route. The study covered the stretch from a point known as Border Marker 2 in the vicinity of Las Tiricias de Cutris in San Carlos, all the way to Delta Costa Rica, at the site of the splitting of the Colorado and San Juan Rivers.

This study recognizes a limitation in the fact that it was not possible to analyze the larger context of the study area due to the fact that the Government of Nicaragua did not allow the scientists conducting this study to enter the Nicaragua area of the San Juan River. Due to the above, it was not possible to conduct sampling and analyze the San Juan River, specifically in the mouths of rivers and channels where they empty into the San Juan River.

Concretely, the study describes the general aspects of the Project that include geographic location, definition of the Project area and areas of influence, general description of the work, risks and system of control of environmental risks.

Several sections of the study offer detailed description of the environment wherein the specific physical and biological conditions (aquatic and terrestrial) of the study area are described and inventoried.

A section on “Environmental Diagnostic” follows where environmental impacts and risks are identified and characterized along with the activities that have potential to create environmental impacts, and this leads to an evaluation of the same and proposed corrective measures. A matrix of importance of the impacts (MIIA) of the project is presented where 11 specific impacts are identified, of which 8 impacts were considered irrelevant and 3 were deemed moderate according to the official SETENA methodology. Also, 5 sources of environmental risk were identified along the whole length of the Route (159,7 km.) that require the introduction of preventive and mitigating measures.

As an integral part of the Environmental Diagnostic Assessment, an “Environmental Adequacy Plan” (PAA) is proposed which consists in a matrix that includes the environmental aspect, the impacts identified, the corrective or compensatory measures, the environmental goals and indicators of environmental performance, the location and frequency of sampling to be conducted, the interpretation and feedback required, and the organization that should be responsible for the execution of the above.

Finally, the study presents a section on conclusions and recommendations intended to facilitate the practical application of the study results on the construction works, which is ultimately aimed at improving the quality of life of the inhabitants and ecosystems in the region of the study.

2 INTRODUCTION

2.1 Background

In the context of the conflict between Costa Rica and Nicaragua due to actions taken by Nicaragua in the Costa Rican territory of Isla Portillos on November 2010, along with other actions displayed by that country, the Government of Costa Rica, in accordance with a National Emergency Decree, has developed a series of civil works in its territory that include the construction of a road along the northern frontier known as Route 1856- the Juan Rafael Mora Porras road.

In response to claims made by the Government of Nicaragua regarding supposed impacts on its territory originated by the construction of Route 1856, the Ministry of Foreign Relations has convened a national and international technical group for the purpose of conducting an exhaustive assessment of the environmental conditions existing along the Route and the potential environmental impacts of the construction.

As part of the effort to conduct an environmental analysis of the Route 1856 project, the Ministry commissioned the services of the Tropical Science Center, given its reputation, technical expertise in the subject, and more than 20 years of experience in research projects in the area, with the purpose of conducting an Environmental Diagnostic Assessment with emphasis in the ecological component.

For such purpose, the TSC met with members of a technical team formed by representatives of the Ministry of Foreign Relations, the Instituto Costarricense de Electricidad, the Ministry of the Environment and Energy and other government advisors.

According to the legal norms of Costa Rica, diagnostic environmental studies, known as EDA, constitute an excellent instrument for environmental evaluation that applies to activities and works already conducted, in order to establish their environmental assessment and to define, within a systematic organizing framework, the series of environmental measures that are needed in order to achieve environmental equilibrium.

2.2 Scope of Study

The Environmental Diagnostic Assessment (EDA)- Ecological Component, is intended to establish the environmental effect of the Route 1856 project based on scientific criteria and to develop an instrument that supports the definition of public policies regarding the environmental actions of the project.

This diagnostic study aims to organize and plan, within the same system, the technical and environmental actions that have been applied, are applicable, and should be applied in the future regarding this project.

2.3 Objetives

2.3.1 General Objective

To formulate the Ecological Component of the Environmental Diagnostic Assessment (EDA), based on the analysis and recommendations defined by the field research and documentary evidence concerning the eventual impacts on the physical and biological environment within the area of the Route 1856 project. This was accomplished through the identification and assessment of the corrective environmental measures that were applied during the construction process, as well as those that will be applicable in the short and mid term, in order for the project to be an environmentally viable operation.

2.3.2 Specific Objectives

- To formulate a general description of the physical environment in the study area where Route 1856 is located.
- To collect and consolidate information on the ecosystems of the region, specifically in the area between Border Landmark 2 and the site known as Delta 7 (Delta Costa Rica).
- To prepare qualitative and quantitative analyses of the possible environmental impacts generated by construction activities related to Route 1856.
- To provide technical scientific foundations that guide the Government of Costa Rica towards decision making in the design and construction of Route 1856.

2.4 Methodology

Regarding the methods utilized to formulate the biological component, a bibliographical review was conducted of studies and research performed in the past by members and other associates of the TSC in the region, along with five field visits by professional team members, and an aerial observation flight, all intended to validate aspects of the characterization of the local ecosystems and the possible environmental factors impacted by work done on Route 1856.

Despite the limited biological information available on the area, previous work and 15 years of field experience by experts Guisselle Monge and Olivier Chassot, as part of the Lapa Verde Program which the TSC develops in the area of the Route project, served to verify and consolidate field information. Likewise, the experience of various consultants in different relevant scientific fields was considered in the formulation of the biological component of the Environmental Diagnostic Assessment (see Annex 9.1).

In order to collect the necessary information to characterize the green coverage and ecosystems present in the area, different studies were analyzed. Even though some of these studies recognize the existence of different natural associations or eco-systems in the border area, no maps were identified to characterize and differentiate these systems in all of Route 1856. Instead, only some limited areas were identified. For this reason, the information on this topic is partial, due in part to the fact that in previous years access to the forests and wetlands of the area was extremely difficult. On the other hand, some of the information that identifies these natural wild lands stretches through extensive areas from the border territory of Rio San Juan for some dozens of kilometres inland.

National forest cover maps offer quantitative information but do not define natural associations as such. Similarly, there are maps of protected areas in the study area, and it is possible to locate some conspicuous ecosystems such as wetlands but not for the whole of the study area, due to the geography of the Route.

To determine predominant natural associations along the Route 1856, aerial photography were analyzed to distinguish among the different types of vegetation, and field verification was carried out later for adjustments in the classification. Primary and secondary forests were determined, as well as their location and general physiographic condition. Furthermore, a generalized slope map was used resulting in the differentiation of two topographic conditions and two distinct and remarkable types of forest associations along Route 1856.

Wetland areas existing within the project´s Direct Influence Areas (DIA) are also located on the map mentioned before. Such wetlands constitute different types of ecological associations. Using the natural cover map, impacted surface in each type of vegetation was quantified.

With respect to the characterization and description of the aquatic fauna in the region, the analysis done covered species identified in previous studies such as textbooks, technical reports, theses and scientific articles.

For the field work, ten bodies of water along Route 1856 were selected in order to study and identify the aquatic macro-invertebrate community abundance and the richness of the taxa, as well as to evaluate the quality of the water applying the BMWP-CR index. These macro-invertebrates were selected as bio-indicators of the quality of the aquatic habitat. Criteria applied for the selection of the sampling sites were:

- Geographic location
- Land Use
- Type of Plant Coverage
- Access, Size and Depth
- Type of Stream Current
- Substrate Availability

Priority was given to tracts where it was deemed probable that environmental impacts existed due to the construction works of Route 1856. Most of these sites corresponded to tracts with steep, unstable slopes and non-consolidated landfills, such as is the case, as an example, of the stretch between Infiernito River and the site of Boca San Carlos on the San Carlos river.

Finally, the structure and guidelines of the present study are based on the Technical Guide for the Environmental Diagnostic Assessment established by the National Technical Environmental Secretariat (SETENA) of the MINAE based on Resolution No. 2572-2009-SETENA of November 2, 2009.

Such document states that “the EDA is an instrument of environmental assessment similar to an Environmental Impact Study (EslA) but instead of being based on predictions, it is based on samples and measurements conducted by an assessment team on an activity, work or project that has been built and is functioning, which does not have an environmental license and whose owner (developer) is interested in obtaining such licence”.

According to the resolution mentioned, the Environmental Diagnostic Assessment addresses the accomplishment of the following technical objectives:

1. To identify and quantify the eventual environmental impacts and risks that a specified activity or project is creating for the environment and the population.
2. To define and establish the necessary measures to eliminate, prevent, attenuate or compensate such significant impacts, for which purpose it must propose a corresponding Environmental Adequacy Program (PAA), as well as a Contingency and Accidents Prevention Program, for cases required or defined by official authorities.

The SETENA also indicates that the EDA is formulated only on significant negative impacts, since its aim is to eliminate, prevent, diminish or compensate negative impacts, and for that purpose operational impacts are evaluated through measurement techniques, making use of environmental measures to avoid, prevent, attenuate or compensate them within a financial equilibrium that does not attempt against the activity that is being evaluated.

2.5 Time frame for the Ecological Component of the EDA

The preparation of the Ecological Component study began with the signing of a contract between the Chancery of the Government of Costa Rica and the Tropical Science Center on May 22 of 2013. Starting with the mutual agreement among the actors, the TSC defined a 4-month period for the development of the Ecological Component and a video that would collect images of the present conditions of Route 1856. For the stated purpose, available bibliography was analyzed, terrestrial and aerial visits within the project area were conducted, and the San Juan river was visited by the study´s professional team.

2.6 Terms of Reference

The analyses performed for the Ecological Component of Route 1856 were based on the environmental guidelines established in Costa Rica by the Ministry of the Environment and Energy (MINAE) according to Ministerial Resolution N° 2572-2009-SETENA, as well as Executive Decree N° 32966 – MINAE, which includes as one of its annexes the Guide for the Formulation of Instruments for Environmental Impact Assessment. This diagnostic study will also adjust to the terms and procedures standardized in Costa Rica for the evaluation of projects being proposed, as well as projects in operation.

These analyses placed emphasis on the road designated as Route 1856, whose initial construction occurred during the period 2011-20123, although for the purpose of the present evaluation includes only the area between Border Marker 2 (Mojon 2) to the site known as Delta 7 (also known as Delta Costa Rica), which refers basically to the section of Route 1856 that runs along the San Juan river all the way to the point where the San Juan bifurcates into the Colorado River.

This EDA-Ecological Component is part of a series of technical reports being developed by different Costa Rican institutions as part of an interdisciplinary effort to contribute to the improvement of road design and construction works.

Even though the study follows a line of development according to the guidelines established in Costa Rican legislation for the formulation of an EDA, two supplementary analysis were developed in order to extend the applications of this study. The first report corresponds to an “Impact Assesment of the Implementation of the Route 1856 on the Development of Tourism Activities in the San Juan River” (See Annex 9.2). The second report is an analysis of structural connectivity in the landscape of Route 1856 (See Annex 9.3). Since the Route is critically

located on the Costa Rica-Nicaragua border, it is of utmost importance to analyze its potential impacts on the conservation of connectivity, based on the identification of priority sites and critical links for connectivity.

2.7 Limitations

The results and evaluations done are limited only to the section of the Route 1856 that begins in Border Landmark 2, close to the site of Tiricias de Cutris de San Carlos, all the way to Delta Costa Rica, across the bifurcation of the Colorado and San Juan rivers.

It is important to note that it was not possible to analyze the results of this study in a larger context within the study area due to the fact that the Government of Nicaragua denied permission to the scientific team to visit the San Juan river. For this reason it was not possible to conduct sampling and analysis within the river, especially in the mouths of rivers and channels that empty into the San Juan and that were included in this study.

3 PROJECT DESCRIPTION

3.1 Geographic Location

Route 1856 is located in the northern territory of Costa Rica, in the provinces of Alajuela and Heredia. The area that corresponds to the study area is located between the following points:

Beginning: Border landmark 2 (Mojon 2), 1215724 North and 526412 East.

End: Site known as Delta 7 or Delta Costa Rica, between coordinates 1190664 North and 460768 East (See map 1).

The design of the Route is contained in 4 topographical sheets at a scale of 1:50,000 by the National Geographic Institute (IGN), which are labelled from northwest to southeast from Border Landmark 2 to Delta Costa Rica, as follows:

- Pocosol 3348-IV
- Infiernito 3348-III
- Cutris 3348-II
- Trinidad 3448-III

3.2 Political and Administrative Location

Along the design of Route 1856 contained in this study, several important provincial, county and district boundaries were identified for purposes of an adequate institutional coordination, decision making, and environmental technical follow-up as required by the Project:

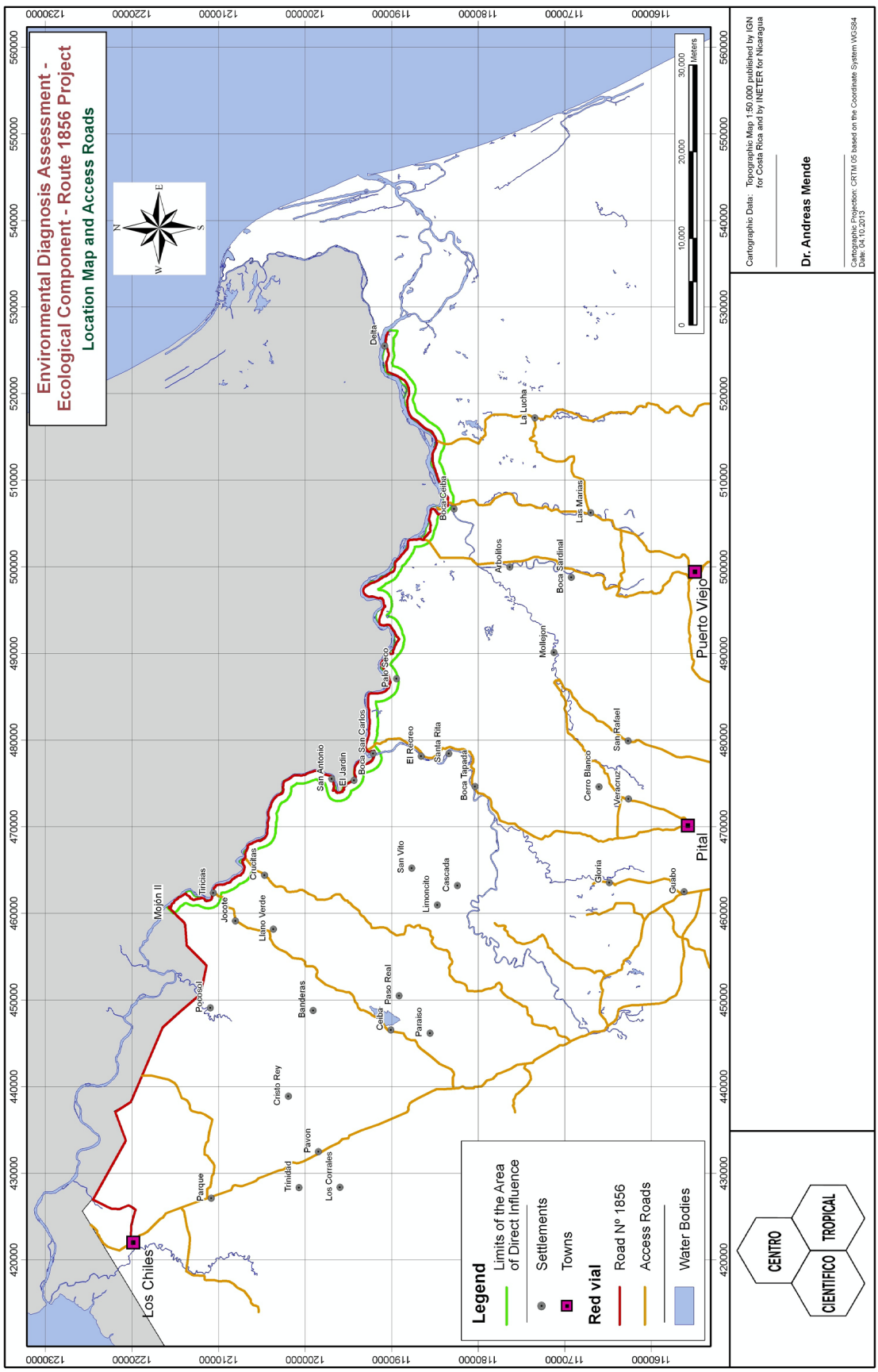
Alajuela (Province 02): San Carlos County and Pocosol, Cutris and Pital districts

Heredia (Province 04): Sarapiquí County and the Cureña, Puerto Viejo and Llanura del Gaspar districts.

3.3 Estimated Project Area and Influence Areas

The study area includes an important segment of tropical evergreen lati-foliated forest and swampy lati-foliated forest (World Bank and CCAD, 2001; Vreugdenhill et al., 2002), with different degrees of human intervention evident, as well as different agriculture and livestock systems in place, in the Northern Caribbean watershed of Costa Rica. In these ecosystems standout perhumid forests rich in trees, epiphytes, palm trees and humid forests that have an average rainfall of 1500 and 3500 mm yearly (Hartshorne, 2002; Chassot et al., 2006a). The territorial framework of the study is determined by the conceptual reference known as the Water and Peace Biosphere Reserve (Moreno and Muller, 2007) and the Biological Corridor San Juan-La Selva (Chassot et al., 2006a).

The study area covers part of the San Carlos and Sarapiquí counties, both of them demonstrating the largest extension of natural land cover on the northern Caribbean territory of Costa Rica. Such areas constitute a mosaic of lands in a natural state and some showing human intervention, and some anthropic use areas that act as buffer zones for those in a natural state (Chassot, 2010).


Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Location Map and Access Roads
Legend
Limits of the Area of Direct Influence
Settlements
Towns
Red vial
Road Nº 1856
Access Roads
Water Bodies
Los Chiles
Puerto Viejo
Pital
Delta
La Lucha
Boca Ceiba
Las Marias
Arbolitos
Boca Sardinal
Mollejon
Palo Seco
San Rafael
Cerro Blanco
Veracruz
Gloria
Guabo
Santa Rita
El Recreo
Boca Tapada
Boca San Carlos
El Jardin
San Antonio
San Vito
Limoncito
Cascada
Crucitas
Tiricias
Mojón II
Jocote
Llano Verde
Pocosol
Banderas
Paso Real
Ceiba
Paraiso
Cristo Rey
Pavon
Trinidad
Los Corrales
Parque
0
10,000
20,000
30,000
Meters
Cartographic Data: Topographic Map 1:50.000 published by IGN for Costa Rica and by INETER for Nicaragua
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO
CIENTIFICO
TROPICAL

The terrestrial buffer zone areas involve some landscape elements that defend the protected wild lands from external threat and also include human communities that cause some type of direct impact on protected wild lands (Groom et al, 1999, Vilhena *et al*., 2004)

Due to the physical and biological characteristics of the region of Route 1856, the ecological analyses contain terrestrial as well as aquatic components. Taking into account the influence of civil works conducted during the construction of the Route, as well as the national legislation on the matter, the Project Area (AP) has been identified as the 50 meters of the right of way of the Route.

On the other hand, the Direct Influence Area (DIA) has been defined as the first 1000 meters from the right margin of the San Juan river towards Costa Rican territory (see Map 1).

Finally, the Indirect Influence Areas (AII) has no uniform extension but is defined by the physical and biological conditions as estimated by each professional member of the team, and, where possible, the conditions of San Juan river were assessed, subject to the access limitations mentioned above.

3.4 General Description of the Activity

The Route 1856 Project consists of the construction of a gravel road that starts at the site known as San Jerónimo de Los Chiles and continues to the site called Delta 7 (Delta Costa Rica). The Project is 159.7 km. in length. Approximately 63.6% (101.5 km.) of the Route´s extension is made up of pre-existing roads and connections in existence over 30 years. The remaining 35.9% (57.4 km.) are new roads that join the existing pathways.

As indicated in section 2.7, the study focuses only on the design of the Route that runs parallel to the San Juan river, which amounts to 108.2 km. of the total route.

The main purpose of the Route was the consolidation of a new terrestrial pathway that would communicate all settlements located between Border Landmark 2 and Delta Costa Rica. This project took advantage primarily of the network of existing roads that run parallel to the San Juan River and built a smaller percentage of roads required to provide continuity to the network.

For the development of this main activity, and as is common in these types of projects, it was necessary to carry out several important secondary actions. Among these were the cleaning of terrain, building up retention slopes, placement of drains and water conduits, and laying a base and rolling surface on the road, among others.

Chart 1 shows the main and secondary components that were part of the activities conducted during the construction of Route 1856.

Chart 1: Activities conducted during the Project construction stage.

N°	Component	Description
1	Clearing and cleaning of new sites	At specific sites along the right of way of the Route.
2	Land movement, retention slopes and land fills	In sections of the right of way where topography and the slope did not permit normal traffic. This was done with the use of heavy machinery (backhoes, heavy trucks, excavators, etc.)
3	Erosion control measures	Installation of systems to control the speed of superficial runoff and sediment control structures.
4	Installation of drainage systems and temporal bridges	Drainage systems and temporal bridges where placed on most rivers and ducts along the Route
5	Road filling, base layer and rolling surface	Commonly needed on any road to permit the transit of vehicles.

In order to better appreciate the Project Area, a series of 6 maps (1:50,000 scale) help to visualize the design of Route 1856 and the land uses in the area (Maps 2, 3, 4, 5, 6 and 7).

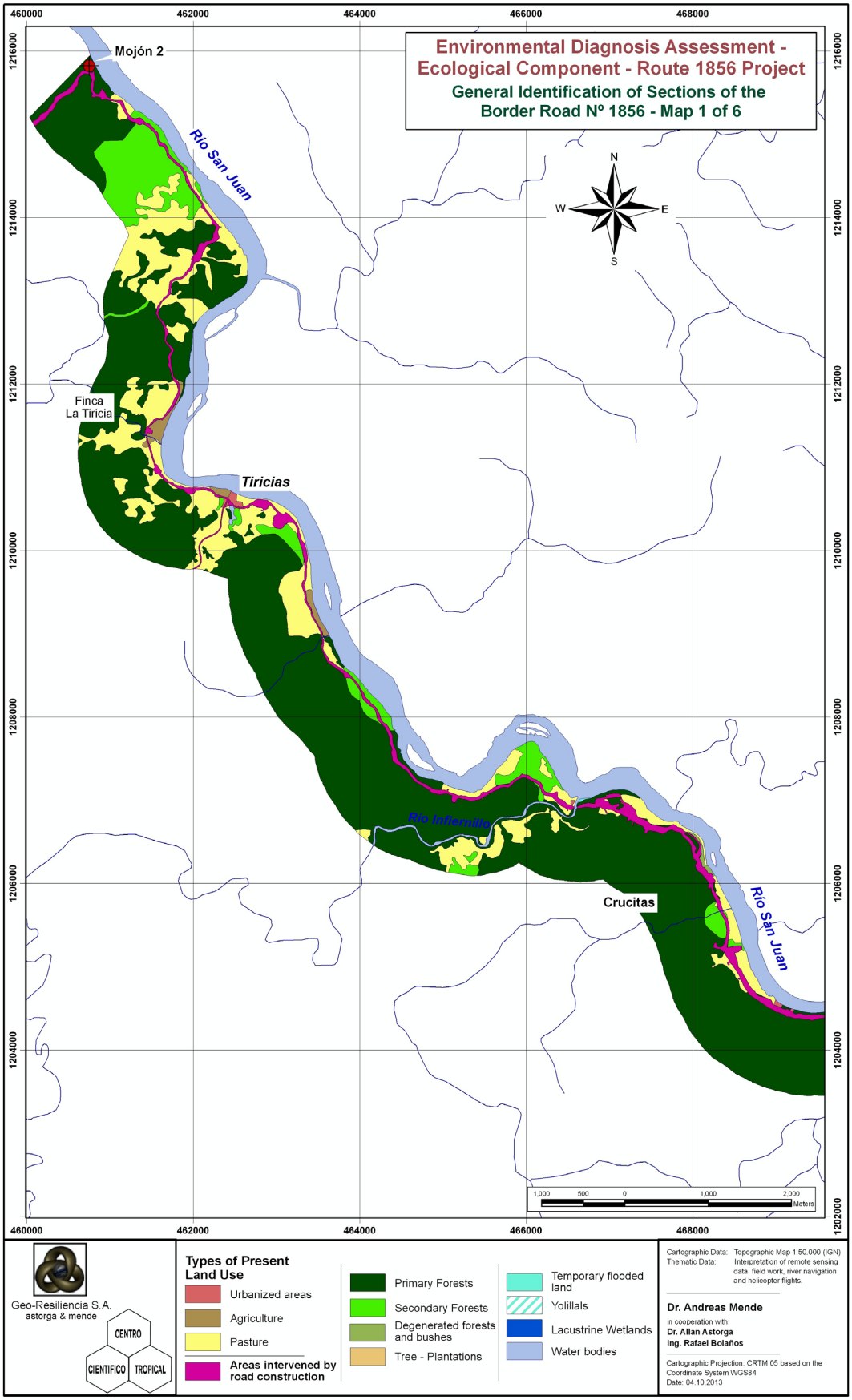
3.5 Environmental Aspects

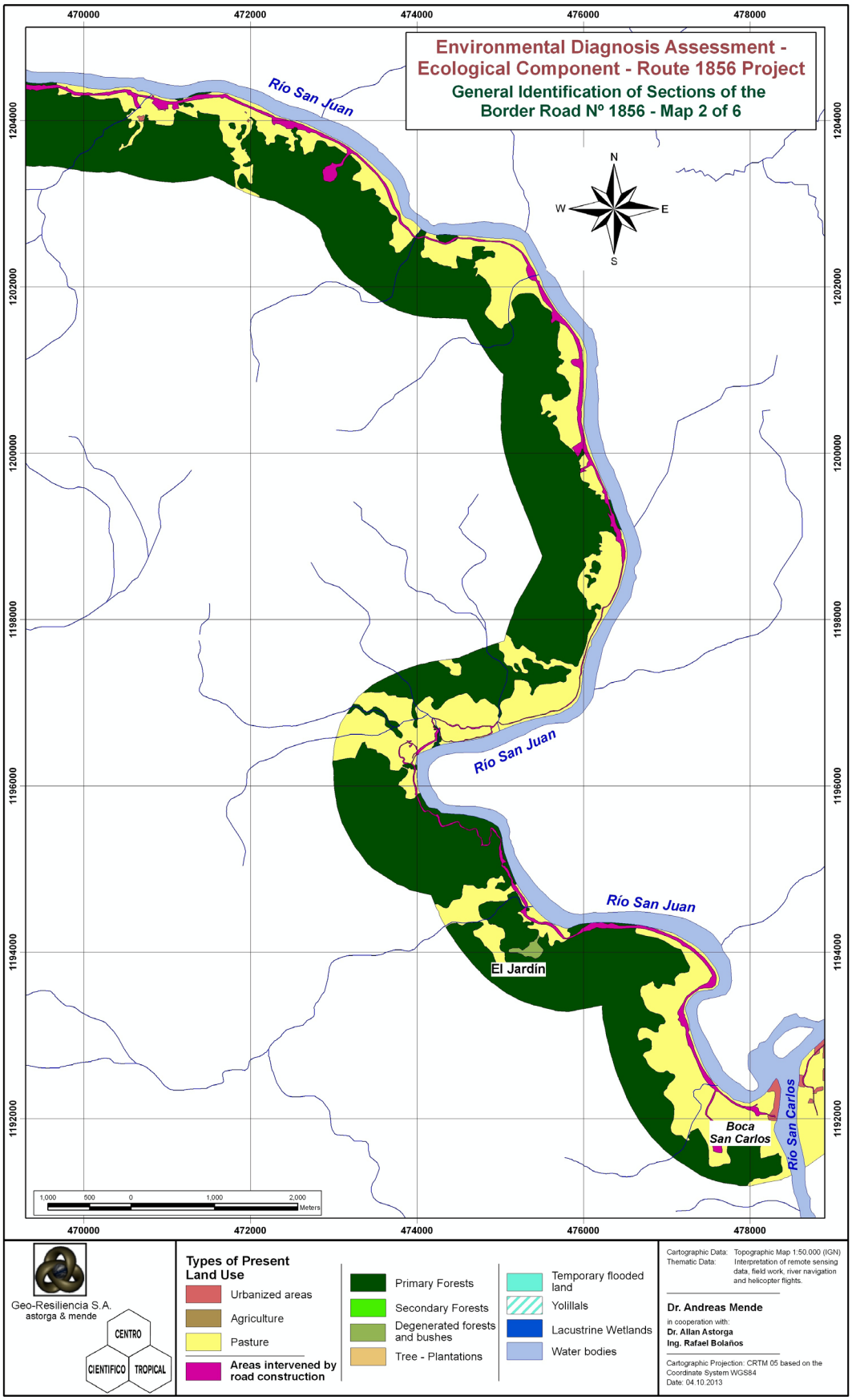
In the previous chapter, a general description was provided of the environment in which the Route project is located and of its construction characteristics, taking into account that large part of the project operates in a totally rural environment. For that reason it is important to establish in greater detail the environmental aspects related to the construction and operation of the project. This will allow a greater approximation to an environmental intervention in accordance to the characteristics of the project.

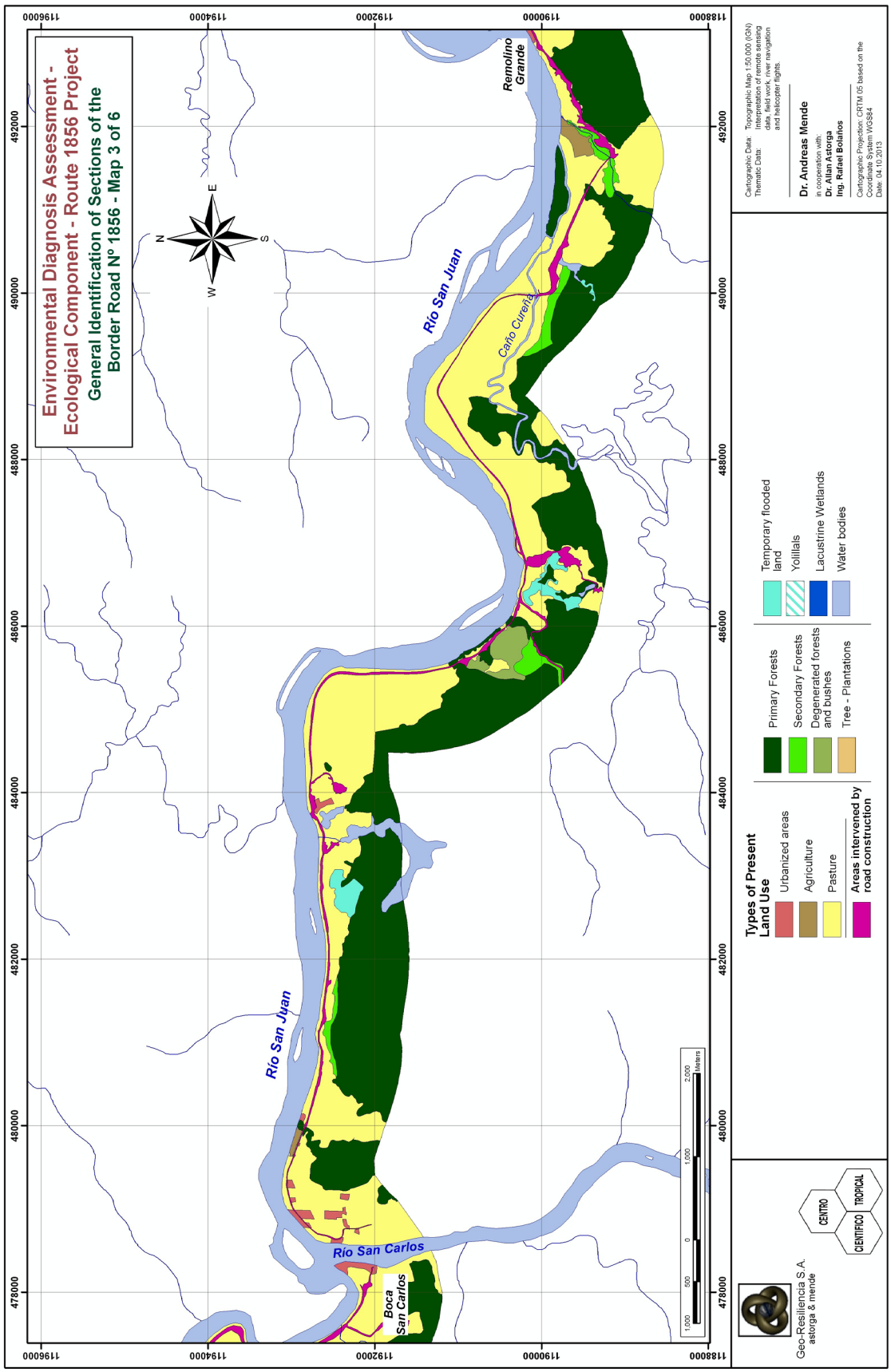
The environmental aspects will correspond with all the actions related to the 1856 Route, which implies some degree of interaction on some environmental component. On the other hand, what is understood as environmental effect is the degree of alteration of the environment, resulting from the previously identified environmental aspects.

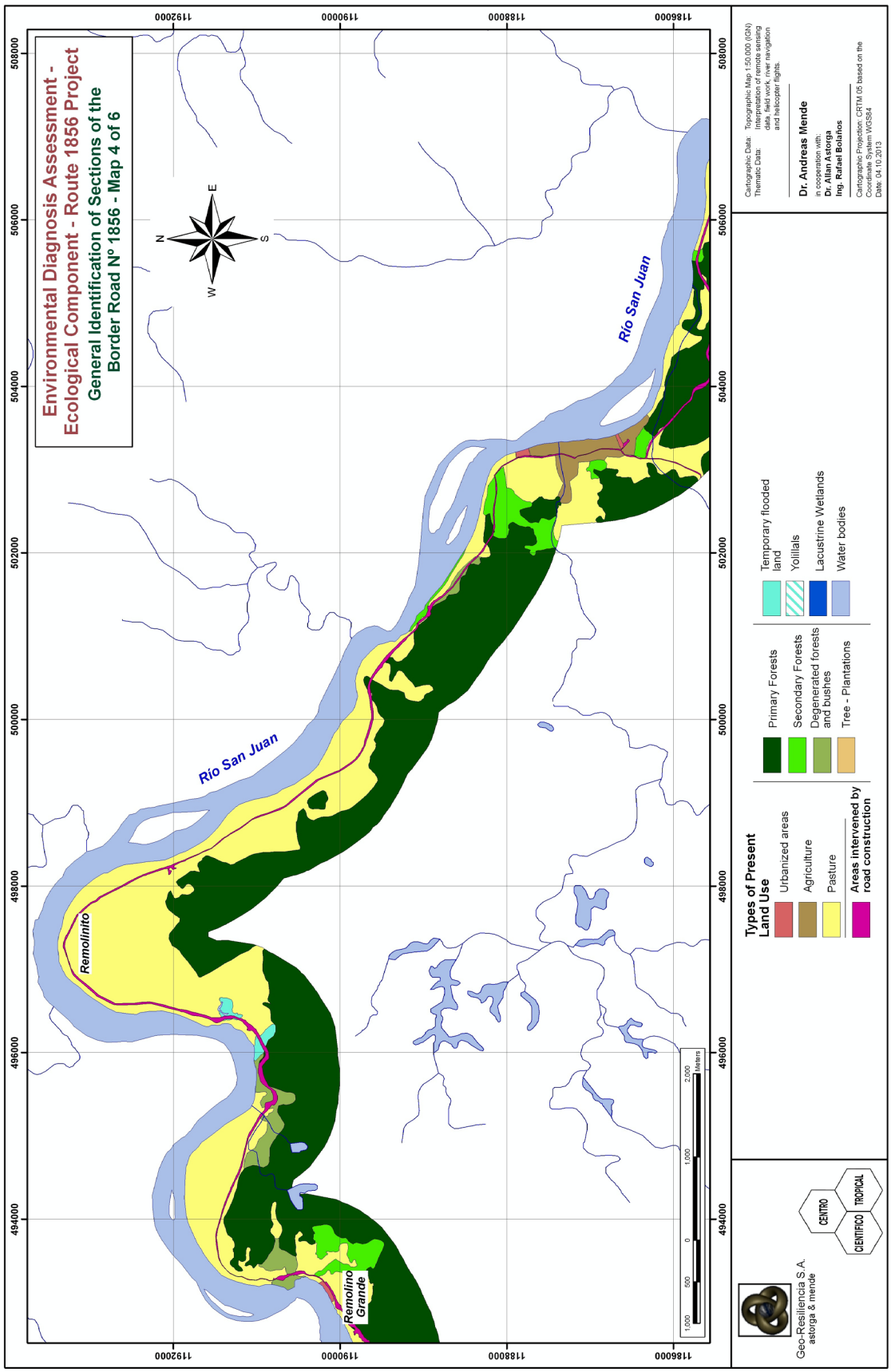
Following are the environmental aspects and their relation to activities of the Route:

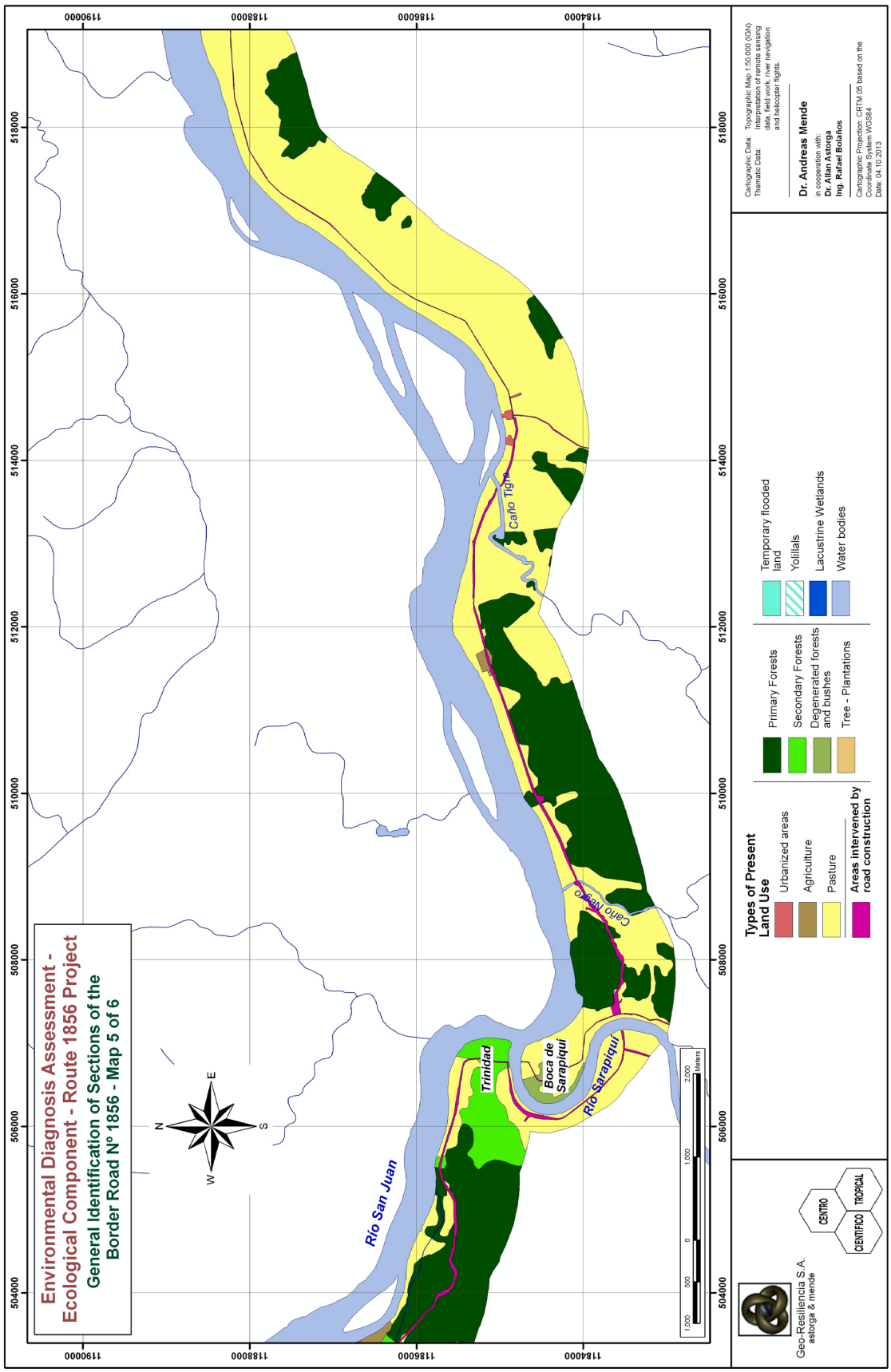
1. Clearing and cleaning of land on sites of road design: this activity is related to the elimination of forest or plant cover along some sections of the Route where no roads were present.
2. Soil movements, building of retention slopes and fills: could generate instability of slopes in some sites where the degree of slope is high. Likewise with the generation of increased surface runoff, laying of sediments in nearby bodies of water and the impact on the scenery in some sections of the Route.
3. Installation of drainage systems and temporal bridges: this factor could be associated to the affectation of aquatic ecosystems on isolated, specific points and the modification of natural drainage systems in the area.
4. Placement of land fills, sub-surface layers and rolling surface: this activity is associated to the possible laying of sediments in some bodies of water close to the Route.

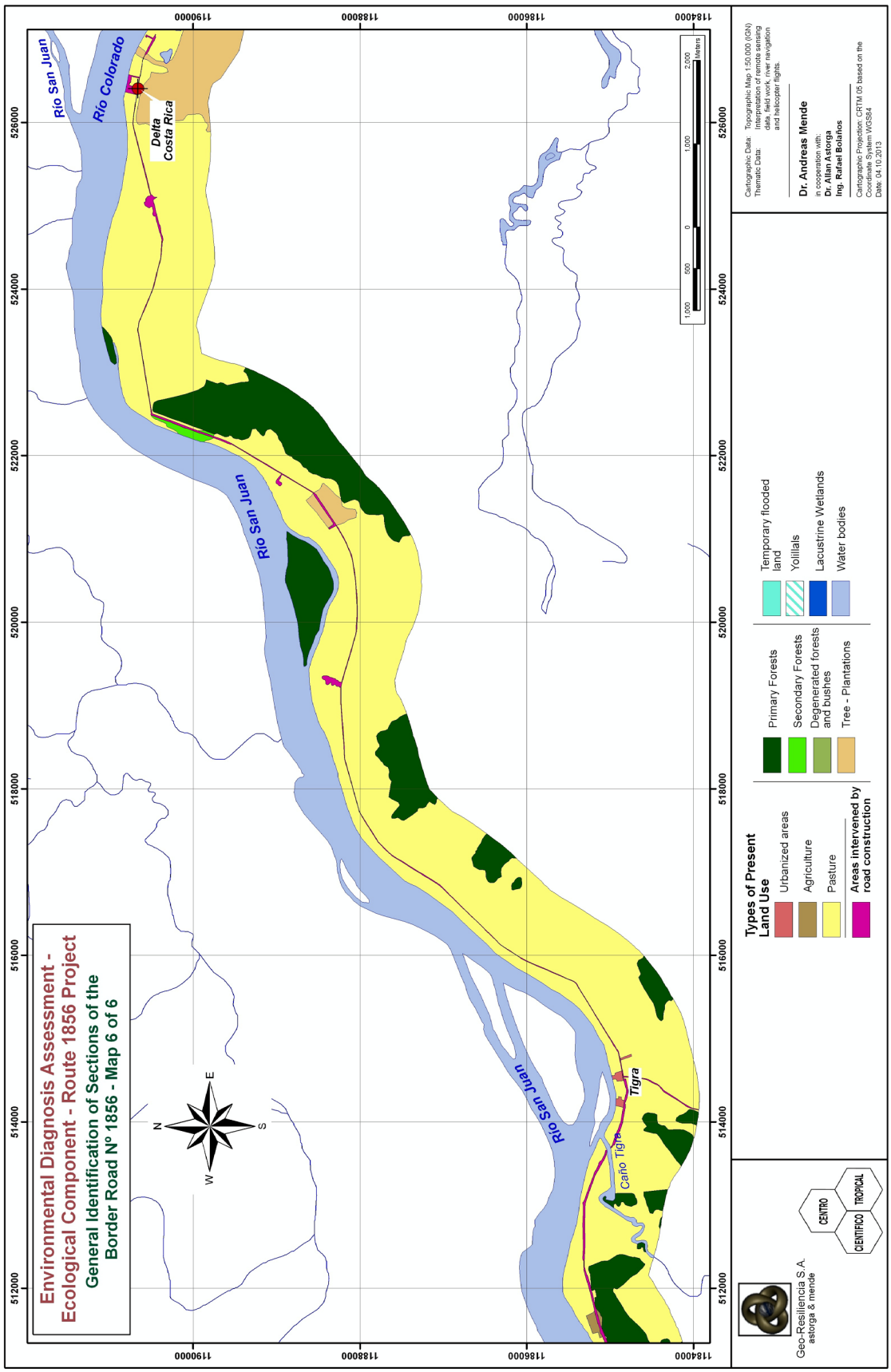

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
General Identification of Sections of the Border Road Nº 1856 - Map 1 of 6
460000
462000
464000
466000
468000
1216000
1214000
1212000
1210000
1208000
1206000
1204000
1202000
Mojón 2
Rio San Juan
Finca La Tiricia
Tiricias
Rio Infiernillo
Crucitas
Rio San Juan
N
W
E
S
1,000 500 0 1,000 2,000 Meters
Geo-Resiliencia S.A.
astorga & mende
CENTRO CIENTIFICO TROPICAL
Types of Present Land Use
Urbanized areas
Agriculture
Pasture
Areas intervened by road construction
Primary Forests
Secondary Forests
Degenerated forests and bushes
Tree - Plantations
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
General Identification of Sections of the Border Road Nº 1856 - Map 2 of 6
Río San Juan
Río San Juan
Río San Juan
El Jardín
Boca San Carlos
Río San Carlos
N
W
E
S
470000
472000
474000
476000
478000
1204000
1202000
1200000
1198000
1196000
1194000
1192000
1,000 500 0 1,000 2,000 Meters
Geo-Resiliencia S.A.
astorga & mende
CENTRO CIENTIFICO TROPICAL
Types of Present Land Use
Urbanized areas
Agriculture
Pasture
Areas intervened by road construction
Primary Forests
Secondary Forests
Degenerated forests and bushes
Tree - Plantations
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
General Identification of Sections of the Border Road Nº 1856 - Map 3 of 6
Río San Juan
Caño Curena
Remolino Grande
Río San Juan
Río San Carlos
Boca San Carlos
Types of Present Land Use
Urbanized areas
Agriculture
Pasture
Areas intervened by road construction
Primary Forests
Secondary Forests
Degenerated forests and bushes
Tree - Plantations
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Geo-Resiliencia S.A.
astorga & mende
CIENTIFICO
CENTRO
TROPICAL


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
General Identification of Sections of the Border Road Nº 1856 - Map 4 of 6
Río San Juan
Río San Juan
Remolinito
Remolino Grande
N
S
E
W
Types of Present Land Use
Urbanized areas
Agriculture
Pasture
Areas intervened by road construction
Primary Forests
Secondary Forests
Degenerated forests and bushes
Tree - Plantations
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Geo-Resiliencia S.A.
astorga & mende
CENTRO
CIENTIFICO
TROPICAL
1.000 500 0 1.000 2.000 Meters
494000
496000
498000
500000
502000
504000
506000
508000
1192000
1190000
1188000
1186000


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
General Identification of Sections of the Border Road Nº 1856 - Map 5 of 6
Río San Juan
Trinidad
Boca de Sarapiqui
Río Sarapiqui
Caño Negro
Caño Tigre
Types of Present Land Use
Urbanized areas
Agriculture
Pasture
Areas intervened by road construction
Primary Forests
Secondary Forests
Degenerated forests and bushes
Tree - Plantations
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Geo-Resiliencia S.A.
astorga & mende
CIENTIFICO
CENTRO
TROPICAL
Meters


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
General Identification of Sections of the Border Road Nº 1856 - Map 6 of 6
Río San Juan
Río Colorado
Delta Costa Rica
Río San Juan
Río San Juan
Caño Tigra
Tigra
N
S
E
W
512000
514000
516000
518000
520000
522000
524000
526000
1184000
1186000
1188000
1190000
1,000 500 0 1,000 2,000 Meters
Types of Present Land Use
Urbanized areas
Agriculture
Pasture
Areas intervened by road construction
Primary Forests
Secondary Forests
Degenerated forests and bushes
Tree - Plantations
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Geo-Resiliencia S.A.
astorga & mende
CENTRO
CIENTIFICO
TROPICAL

Starting with the previously stated, four activities have been identified which are associated with possible environmental impacts. Each one of them will be described in greater detail in the section that deals with Identification and Evaluation of Environmental Impacts.

3.6 Environmental Risk Control System

According to the activities conducted for the Project, some sources of environmental risk were identified and measures implemented in order to avoid the alteration of the terrestrial and aquatic environment. These are presented below.

3.6.1 Risk of Cutting Down Trees which are in Danger of Extinction

The possibility of cutting down trees that are in danger of extinction due to the land clearing and cleaning activities in some sites of the Route, was minimized as a result of the tree inventory performed by the National Highway Council (CONAVI) during the construction of the project. It should be pointed out that currently there is a reforestation plan that is being implemented by CODEFORSA since 2012 that has planted some 26,000 trees native to the zone along the strip of land that surrounds the Route.

3.6.2 Risk of Slope Erosion and Slope Instability

This risk appears as a consequence of an inadequate design of drainage systems and a lack of proper protection of slopes along the road. This can be prevented with adequate drainage construction in different sections of the slopes to avoid runoff on the face of the slope, the generation of furrows or grooves, bumps and destruction of terraces. This risk has also been controlled with the placement of geo-textiles and, even better, with the planting of grasses on the slopes with the idea of diminishing the direct impact of rainfall on the exposed surface.

3.6.3 Risk of Altering Natural Drainage Systems

There is a risk present of modifying the natural drainage patterns of the different bodies of water along the Route, particularly the drainage systems of still waters and wetlands along specific sections. Based on the previously mentioned, a partial control is conducted of the structures to avoid the natural action of the drainage which existed before the construction of the Route. Greater control must be established of the correct functioning of different waterways.

3.6.4 Risk of Obstructing Waterways

There is risk of obstructing rivers, creeks and channels in some sections of the Route, specifically in points where temporal structures in poor condition were laid to facilitate movement across such bodies of water. The possibility of collapse and the falling of trees, steel beams and construction materials could cause artificial obstruction of waterways, generate floods and changes in the natural drainage system and erosion along the margins.

To avoid this situation, a periodic monitoring effort has been conducted of Route 1856 by COSEVI, promoting an adequate preventive control of the structures along the way. Nevertheless, it is necessary to establish more rigorous preventive and corrective measures.

3.6.5 Risk of Eroded Sediments Depositing on Bodies of Water

Due to the high rate of rainfall in the area of the Route, the high grade of weathering of the geological materials that are part of the ground, and the absence of forest cover in some specific sites, the existence of the potential risk of eroded sediments depositing on the different bodies of water has been identified.

As a preventive measure runoff control systems have been put into place, as well as sediment traps along the Route. These measures must be complemented with monitoring systems to verify the control of sediments in suspension.

4 DESCRIPTION OF THE PHYSICAL ENVIRONMENT

4.1 Geology of the Study Area

4.1.1 Regional Tectonic Framework

Costa Rica is located on the southwestern margin of the Caribbean Tectonic Plate and is part of the mature intra-oceanic arch of southern Central America, of Superior Cretacian age (Astorga et al., 1991). Some of the tectonic characteristics with strong influence in the Northern area of Costa Rica are described by Astorga et al. (1991):

a. The North American Trench, where the Cocos Plate slides under the Caribbean Plate, and which includes the subduction of the submarine range named Dorsal Asysmic Cocos, in the South Pacific of Costa Rica.

b. The Hess Scarp, interpreted as the trace of a fault, with a possible trans-current movement, with activity present mainly during the pre-Cenozoic period (Bowland 1984; Astorga et al, 1991) and which separates the Rising of Nicaragua and the Colombia Watershed (Mann and Burke, 1984 in Astorga et al., 1991)

c. The Nicaragua Depression (McBirney and Williams, 1965 in Astorga et al, 1991) which extends to the trans-arch region of northern Costa Rica and which belongs to a system of trenches (graben) belonging to the Late Neogene (Mann and Burke, 1984 in Astorga et al, 1991), whose origin is associated (Mann, 1990 in Astorga et al, 1991) with an extension of the trans-arch area due to subduction, subsidence among dextral trans-current faults disposed along the borders and by combination of both processes.

Astorga (1991) classifies two generations of sedimentary watersheds for Costa Rica, according to the geodynamic evolution and the interaction among the previous and other tectonic characteristics. The first generation is formed by watersheds of intra-oceanic island arches which contain the morpho-tectonic units corresponding to the Trincher, *Arco Externo* and *Arco Interno*, with ages that go from the Superior Cretaceous to the present. It includes the Northern Limón watershed as a trans-arch watershed, which presents two generations of normal faults, one aged in the Oligocene- Miocene and another one in the Miocene Superior-Pliocene.

The second generation is formed by the watersheds superimposed on the arch of islands, originated by local tectonic phenomena during the Late Tertiary (Astorga, 1991), mainly by trans-tensive mechanisms associated to trans-current faults, which makes the San Carlos watershed a second generation watershed of the extensional type. Nevertheless, this watershed does not show important deformation structures that can be correlated with the deformation phases defined by Gursky (1988) for the northwest of Costa Rica, and thus it is considered a marginal watershed, tectonically passive, of the Northern Costa Rica Segment.

4.1.2 Regional Geology

Geologically, the area under study is formed mainly from volcanic and volcano-clastic rocks of the Superior Tertiary period, which have been named the “Sarapiqui Arch” (Astorga 1992). This arch has a basement of serpentinized ophiolites of Cretacian age.

The exogenous processes have originated a sedimentation process of materials coming from the Sarapiquí Arch, and it is thus that the San Carlos watershed as well as the Northern Caribbean watershed, have a filling of Quaternary deposits.

4.1.2.1 Ophiolites of Tiricias

The Ophiolites of Tiricias are formed from serpentinized peridotitic rocks which are considered to be the base of the Sarapiquí Arch (Astorga 1992). A small upcrop of these serpentine rocks described by Astorga (1992), 6 km. west of the site of Tiricias, close to the border of Nicaragua, has been correlated with the presence of serpentine rocks at 1920 meters deep in the Tonjibe well, perforated by the Costa Rican Petroleum Refinery (RECOPE). The existence of these serpentine rocks in the surface, as well as in great depth, leads to the interpretation of the existence of a rock base of Mesozoic oceanic cortex in this section of the trans-arch, with a tectonic emplacement by accretion (Astorga 1997), with a minimal age of Superior Albiano (Astorga 1991). Tournon and Bellon (2009) consider that due to their texture and composition these ophiolites are typical peridotites of the mantle, similar to those of the Santa Elena Peninsula in Guanacaste, which leads them to interpret their origin as part of the proto-Caribbean base layer.

4.1.2.2 Sarapiquí Arch

The Sarapiquí Arch is probably a remnant of a volcanic arch with volcanic activity during the pre-Pliocene (Astorga 1991). Gazel et al. (2005) assign a Miocene age between 22.2 and 11.3 Ma to it with a composition of olvinic and riolitic basalts represented by lavic faces, pyroclastic deposits and sub-volcanic bodies.

4.1.2.3 Quaternary Deposits

Quaternary deposits of the San Carlos *graben* are formed by volcano-clastic deposits and marginal volcanites (Astorga, 1991). This sedimentation process starts during the Pliocene with a concise clastic marine sedimentation (Astorga 1991).

The trans-arch watershed of Northern Limón is filled with marine clastic sediments, which pro-grade towards the Colombia watershed, without major tectonic distortions (Astorga, 1991). It is possible that the formation of the delta of the San Juan River mouth occurred during the Superior Miocene.

4.1.3 Seismic Activity

The Northern Caribbean region is a region of low seismic activity. Nevertheless, in 2012 and after the Sámara Earthquake of September 5, 2012, 9 earth tremors were recorded along the Colorado River, close to the Nicaraguan border, with magnitudes (Mw) of 3.1 up to 3.9 (Barquero 2013)

The alignment of the epicenters of such seismic activity coincide with the Colorado River, with a northwestern to southeastern orientation, which suggests the presence of an active fault. This recent sismic activity could accelerate exogenous processes and increase the sedimentation rate towards the San Juan River.

4.2 Geomorphology

The design of the Route includes morphologies of volcanic ranges of the Tertiary period, related to the Sarapiquí Arch. These ranges contrast with the lowlands of San Carlos, which are composed of sediments of the Quaternary period and are found in the San Carlos and Northern Caribbean watersheds.

Within the Quaternary morphologies neighbouring the San Juan river, coexist fans or alluvial cones which provide materials of volcanic composition and whose morphologies mix with those of the lowlands in the area.

4.2.1 Morphologies of Tertiary Vulcanism of the Extreme North of Costa Rica (Bergoeing et al., 1997)

On the southern margin of the San Juan river, on the northern limit of the tectonic trench or *graben* of Nicaragua, a volcanic range of the Tertiary Period arises with an altitude of 250 meters above sea level (m.a.s.l) which contrasts with the lowlands that do not surpass the altitude of 50 m.a.s.l.

According to Bergoeing et al. (1997), such morphologies lead to a multi-convex model due to the alterations caused by volcanic material.

4.2.2 Morphologies of Alluvial Quaternary Cones in Northern Costa Rica (Bergoeing et al., 1997)

A series of coalescent dejection cones mark the limits between the Central Volcanic Range and the lowlands of San Carlos. Such cones are cut across by a fault with steep slopes that marks the southern limit of the Nicaragua *graben*. From this boundary and extending for some 50 km. a series of fans or alluvial cones of volcanic composition, with a red clay matrix, have developed. These cones began to form during the Median to Superior Pleistocene, evolving towards a series of glacis during the Upper Pleistocene-Holocene, where they mix with the pre-existing lowlands.

The alluvial cones described possess a multi-convex model, proper to lowland soils in tropical environments (Bergoeing et al. 1997). In the lowlands are also found paleo-meandric morphologies which were probably active during the Superior Pleistocene (Bergoeing et al. 1997).

4.2.3 Sedimentary Quaternary Morphologies

Bergoeing et al., 1997, divide the sedimentary deposits of the lowlands in the San Carlos and Northern Caribbean watersheds into Quaternary deposits of the Upper Pleistocene and Quaternary deposits of the Holocene. The Upper Pleistocene deposits are found closer to the morphologies of the Tertiary volcanic activity, so that they could be interpreted as a product of the erosion of volcanic remainders.

Within the Holocene deposits is found the delta of the San Juan river, which divides into two arms due to the fluvial terrace built up by the sediments of the San Juan river, starting in the Upper Pleistocene and on to the Holocene (Bergoeing, 1997)

4.3 Soils

The region of Route 1856 contains soils of the Ultisol class (Vasquez 1985) corresponding to the class of oldest and most weathered soils in the country. These are common in the Northern region (Sarapiquí, San Carlos, Cutris), in the southern region (Perez Zeledón, Buenos Aires and the border region of Panamá) as well as in the lower altitudes of the Talamanca Mountain Range, both Pacific and Atlantic sides.

In terms of mineral content, there is a predominance of clays in the order of 1:1 (mainly Caolinite) and oxides of Fe and Al. Although these materials are fine, the formation of H bridges in the 1:1 facilitates that particles stick together creating more developed structures. These in turn are covered by oxides and constitute a type of particle of larger size which is known as "pseudo-arena".

4.4 Climate

According to data of the Meteorological Institute, the Northern Zone is the third most rainy region in the country with a rainfall rate greater than 3,200 mm. annual average. According to Bergoeing (2008) the region belongs to a structural unit known as the Nicaragua Trench, which extends from Nicaragua to the Southern Caribbean region of Costa Rica.

This region belongs to the rainfall regime of the Caribbean Coast, which has a rainy season that stretches throughout the year, with a decrease in rainfall during the months of February, March and April. It is a region of diverse rainfall conditions with an interaction among the climatic elements and the geographic conditions of the region, among them extensive lowlands, low altitude mountain ranges, wetlands and lagoons, including the influence of the extensive lake of Nicaragua.

4.4.1 Micro-climates

In general, the climate of this region is determined by atmospheric systems of large magnitude such as the Inter-tropical Convergence Zone (ICZ), the Eastern Waves and the modified cold fronts from the North, which are sources of instability. Also influential are the hurricanes in the Caribbean Ocean, particularly those that come close to, or even penetrate, the Central American Isthmus.

The ICZ determines in large measure the general climate of the country during the period of May to December, particularly on the Pacific Watershed, originating frequent and abundant rainfall (Chassot et al. 2006).

In correlation with these conditions of the humid tropical region, the temperature averages 29 º C (Holdridge 1987). This environmental condition combined favours a high relative humidity all year round. In high places, such as Tamborcito mountain (101 m.a.s.l.) or the top of El Recreo range, the climate is colder and windy.

Relative humidity is 85% on average during a great part of the year, with a few exceptional colder days (22 º C). The most humid period extends from July to October (Chassot and Monge 2002) with an average humidity of 90%. The wind factor displays two behaviours during the year: prevalent winds from February to May are westerly, related to equatorial currents from the Pacific region. From June to November easterly winds are dominant, with low velocities. During hurricane events on the Caribbean Ocean, the winds follow the direction of the large air masses

that move from the West to the Caribbean with gusts of 50 km/hour. Between December and January, the dominant winds are from the North.

4.4.2 Rainfall

In the project area the average annual rainfall varies between 2300 millimeters and 4400 millimeters.

4.4.3 Temperature

The average annual temperature for the plains areas approximates 26 to 27 º C and the higher elevations such as the Chaparron Mountain and Las Crucitas, the median annual temperature may be as low as one degree centigrade.

4.4.4 Solar Brightness

The average sunlight hours can reach up to a maximum of 5 hours. The whole region is influenced by large nuclei generated by evaporation.

4.4.5 Dry Months

According to existing information in the historical records of the National Meteorological Institute, a dry season is not present as such in the area. Rather, a partial decrease in rainfall during a period of 3 months, February through April, is identified.

4.5 Hydrology/ Hydrography

Costa Rica has 34 important hydrographic watersheds, with 17 of them on the Caribbean side and 7 of them emptying in the San Juan river. The main rivers in the area of the 1856 Route are the Sarapiquí, the San Carlos and the San Juan rivers, with the latter being the receptor of the waters of the previous two. The San Carlos and Sarapiquí rivers are among the most important ones in the country´s hydrographic system.

Chart2: Hydrographic Watersheds in the Study Area

Major watershed	Medium watershed	Minor watershed	Area (hectares)
Río San Juan	Río San Carlos	Río San Carlos	3783.4
		Río Tres Amigos	27.9
		Quebrada Rosalía	1035.9
		Caño Boca Tapada	1694.1
		Caño Canacas	1033.4
		Caño Cerritos Gemelos	186.8
		Caño El Jardín	2436.0
		Caño La Mona	916.8
		Caño Pataste	4353.2

Major watershed	Medium watershed	Minor watershed	Area (hectares)
		Caño Recreo	906.4
		Caño Sucio	4672.5
	Río Sarapiquí	Río Toro	872.8
		Río Sarapiquí	1611.3
		Quebrada Grande	168.0
	Río San Juan	Río Cureñón-Caño Cureña	14271.2
		Río San Juan	1389.3
		Quebrada – Caño Copalchí	8562.5
		Caño Tambor	7636.1
		Caño El Chile	254.2
		Caño Cureñita	3881.7

Source: Chassot *et al*., 2006.

5 DESCRIPTION OF THE BIOLOGICAL ENVIRONMENT

5.1 Introduction

During recent years, the country´s legal framework has been characterized by its attempts to regulate in a more integral manner the relationship between humans and their environment, and to organize the appropriate use of available natural resources. In this sense, Article 50 of the Political Constitution is aimed at the promotion of sustainable development; that is to say, development which is compatible with the environment. This article states:

"The Government shall procure the greatest wellbeing to inhabitants of the country, by organinzing and encouraging production and equitable distribution of richness. Every person has the right to a sound, ecologically balanced environment. Is therefore entitled to denounce any acts that violate the law and to claim compensation for damage caused. The Government shall guarantee, defend and preserve that right. The law shall determine the corresponding responsibilities and penalties" (Article ammended by Law No. 7412, on May 24, 1994, published in La Gaceta No. 111, June 10, 1994).

In the area of Route 1856, different technical studies have underscored the importance of promoting and consolidating activities that support the conservation of native forest patches, as well as the importance of promoting recovery actions that assure the permanence of the biological routes that are travel paths for different species, among them the Great Green Macaw Ara ambiguus, a species that is currently under threat of extinction. For this reason Costa Rica has acquired a number of national and international commitments that lead the country to take appropriate measures, within its means, to preserve the environment and protect bi-national species and habitats.

In addition to the standard norms, the geographic area of Route 1856, has specific norms that reinforce the legal and political commitments assumed by the State of Costa Rica to foster conservation and sustainable management in that region. Among these stands out the Agreement on Border Territories signed by the governments of Costa Rica and Nicaragua on the 15 of December, 1990, which establishes the International System of Protected Areas for Peace (SIAPAZ).

As part of the system a number of actions have been implemented for the integrated management of natural protected areas in Southeastern Nicaragua and the northern region of Costa Rica; one of these is the establishment of the El Castillo-San Juan-La Selva Binational Biological Corridor as one single biological unit (Chassot *et al.*, 2006).

On the other hand, the Mesoamerican Biological Corridor (CBM) is a regional initiative that is intended to maintain the ecological connectivity between North and South America, with the goal of preserving migration routes and the transmission of genetic flux through the Central American isthmus (CBM 2002). The Atlantic Humid Tropical Forest of Northern Costa Rica contains the last remnant of lowland habitat with potential of maintaining continuity of the Mesoamerican Biological Corridor between Costa Rica and Nicaragua, the largest gap on the Atlantic route between Honduras and Colombia (Chassot *et al.*, 2005; Villate et al. 2008).

The El Castillo-San Juan-La Selva corridor arises as a management strategy that responds also to a territorial organizational and zoning scheme that maintains the connectivity of the Mesoamerican corridor. The importance of the northern territory of Costa Rica, in addition to the presence of wetlands of high biological value, it contains the last remnant of very humid tropical forest where the mountain almond tree (Dipteryx panamensis) is a dominant species. It is also home to numerous threatened species, among them the emblem species: jaguar (Panthera Onca), the sea cow (Trichechus manatus) and the Great Green Macaw, a species that is highly dependent on the almond tree as a source of nourishment and substratum for nesting. (Chassot *et al*. 2006).

The San Juan River is an important navigation route. It is the river that empties Lake Cocibolca (Lake Nicaragua). Within the interest areas, along the superior branch and up to the confluence with the San Carlos River, it is narrow, deep, without islands and with some rapids. After it joins the San Carlos River, it broadens its course (Chassot and Monge, 2002), it becomes shallow, islets appear and it ends in a delta when it reaches the Caribbean Ocean. The main input for its waters comes from the tributary watersheds of the right margin,that is the San Carlos, Sarapiquí and Chirripó rivers. These rivers provide 65% of the total volume of the San Juan River. Indeed, the San Juan River, before receiving the waters of the San Carlos River, carries approximately 474 m^3/s and after receiving the waters of the San Carlos it goes up to 833m^3/s, a volume that increases to1308 m^3/s with the addition of the Sarapiquí waters, (Chassot and Monge, 2002); it later increases again by 191 m^3/s with the added waters of the Chirripó river.

5.1.1 Terrestrial Environment

The region adjacent to the San Juan River, on the Costa Rican margin, has been a territory marked by migratory processes and intermittent colonization. Until the 1950s, the area where Route 1856 is located was dominated by subsistence agriculture and domestic use. The weak agriculture production of the local farmers is complemented by fishing and hunting in neighbouring areas. The poor soils in the area have frustrated any attempts to develop the productive capacity of the land.

Presently, the main productive activities in the region are cattle raising and agriculture (basic grains, root crops, palm and citric crops). During the last couple of decades, cattle farms have begun to change to exotic monoculture plantations (mainly Melina and Teca).

All of the above mentioned activities and events have occurred through the years inside the National Wildlife Refuge Border Corridor. Families that have lived within the refuge for more than 40 years have been given rights to the property and its use. (Chassot *et al.,* 2006)

5.1.1.1 Protection Status (Protected Areas)

The establishment of the Natural Protected Areas system in Costa Rica began in 1955. Because of the problems of landscape fragmentation resulting from the expansion of the agricultural frontier, the small size of protected areas, and given the need to plan these areas with an integrated perspective, in 1988 it became necessary to create the system of protected areas through the establishment of the National Conservation System (SINAC) in 1999. This required the integration of the three main directing offices within the Ministry of Natural Resources, Energy and Mines: the Forestry, Wildlife and National Parks offices; offices which were in charge of protected areas under different management categories. This integration process was legally consolidated in 1998, with the approval of the Biodiversity Law No. 7788 (Mena *et al*., 1998).

Presently, the country is divided administratively into 11 conservation areas, responsible for directing the management of protected areas within its geographic area. In this manner, within the study area of Route 1856, there are three conservation areas: the Arenal Huetar Norte Conservation Area (ACAHN), the Central Volcanic Range Conservation Area (ACCVC), and the Tortuguero Conservation Area (ACTo), (See Map 8).

The protected area Costa Rica-Nicaragua Border CorridorNational Wildlife Refuge, created by Executive Decree No. 22962-MIRENEM, 1994) is found within the ACAHN, ACCVC and ACTo conservation areas. The corridor includes all of the border strip from the Pacific to the Atlantic Coast, with a width of 2 kilometers (Rio San Juan-Amigos de la Tierra Project, 2000). This is the only protected area that is directly affected by the design of Route 1856 which is included in the route design between Border Mark 2 and Delta Costa Rica.

Other important conservation designations are found within the National Wildlife Refuge Costa Rica-Nicaragua Border Corridor such as the Northeastern Caribbean Ramsar Wetland (created by Ramsar convention in March 1996), the Maquenque Ramsar Wetland (Ramsar convention of October 2010) and the Water and Peace Biosphere Reserve (created by UNESCO in September 2007).

The Northeastern Caribbean Wetland located on the northern Caribbean Coast of Costa Rica, has lagoons, swamps and flooded forests with “yolillo” palm (*Raphia taedigera*).

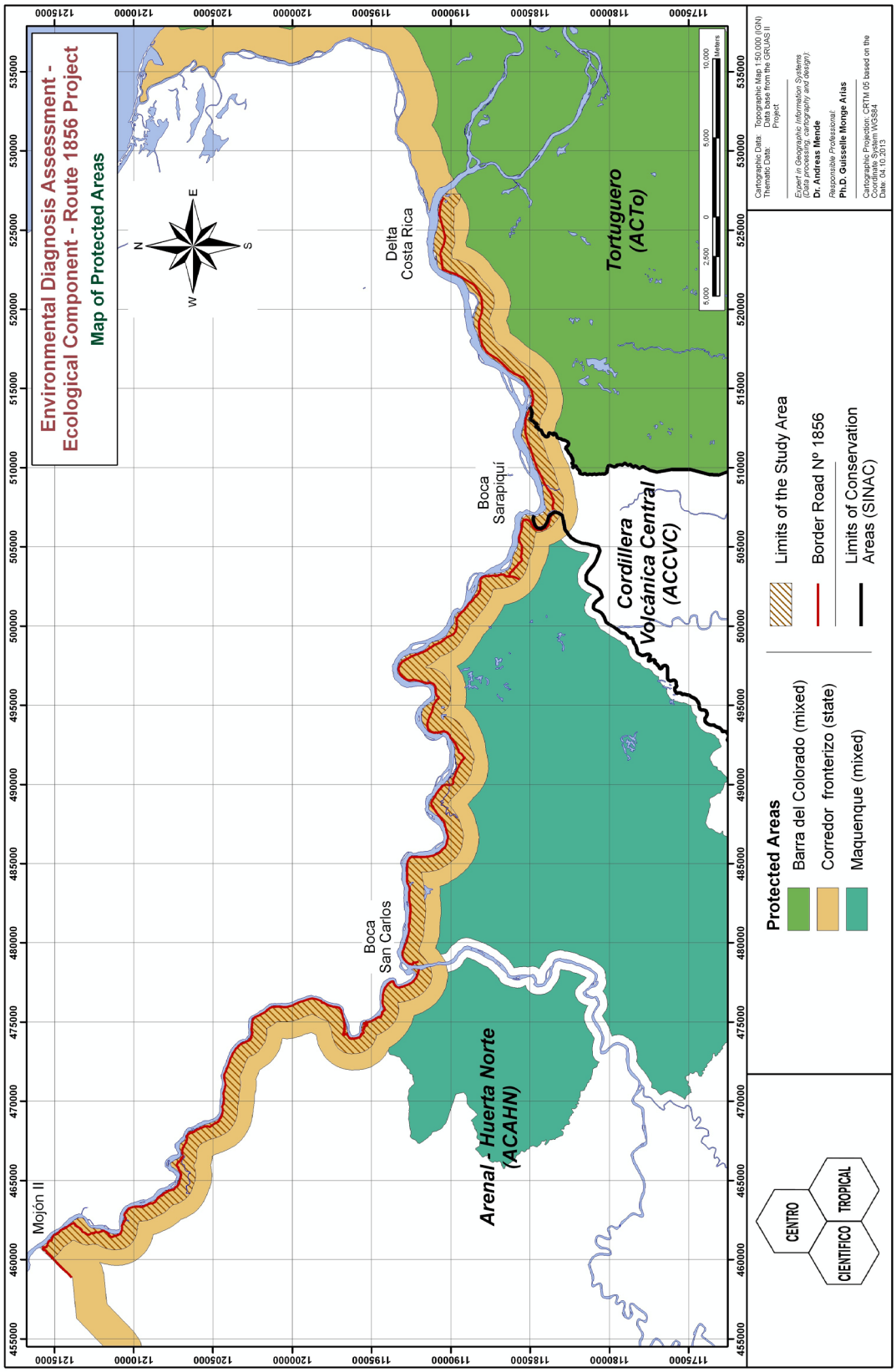
The Maquenque Wetlands contains a complex of lakes and palustrine ecosystems common to an ecoregionof very humid tropical forests and characterized by high biodiversity where it sustains a number of threatened species such as the Great Green Macaw (*Ara ambiguus*), vulnerable species such as the Manatee (*Trichecus manatus*) and other signal species such as the Jaguar (*Panthera Onca*) and the Gaspar fish (*Atractosteus tropicus*) (Tropical Science Center, 2008).

The Water and Peace Biosphere Reserve holds great natural riches that include wetlands, navigable rivers, tropical wet forests and great water springs (Moreno and Muller, 2007).

Finally, the Maquenque Mixed National Wildlife Refuge (created by Executive Decree No. 32405-MINAE 2005), is located south of the Indio Maiz Biological Reserve, next to the National Wildlife Refuge Costa Rica-Nicaragua Border Corridor, less than 2 km. from the Route 1856 design, and contains the largest area and best representation of the lowland forests in the Caribbean slope of Costa Rica.

The San Juan-La Selva Biological Corridor (246,608 hectares) fills the conservation gap between Southeastern Nicaragua and the lowlands of the northern region of Costa Rica, preserving the connection between eco-systems in the Central Volcanic Range and the La Selva Biological Station (125,691 hectares) in Northern Costa Rica, with Barra del Colorado National Wildlife Refuge (102,165 hectares) and the Tortuguero National Park (29,068) along the Caribbean Coast of Costa Rica, and, in turn, with the extensive complex that includes the Indio Maiz Biological Preserve (306,980 hectares), Punta Gorda (54,900 hectares) and Cerro Silva (339,400) in Southeastern Nicaragua.

The central conservation unit of the San Juan-La Selva Biological Corridor is the Maquenque Mixed National Wildlife Refuge, which contains the largest area of the corridor with the largest percentage of forest cover. The main goals of this initiative is the preservation of the movement routes documented for wildlife that connects key habitats to prevent isolation or loss of species and the preservation of the ecosystem functions.


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Map of Protected Areas
Mojón II
Boca San Carlos
Boca Sarapiquí
Delta Costa Rica
Arenal - Huerta Norte (ACAHN)
Cordillera Volcánica Central (ACCVC)
Tortuguero (ACTo)
Protected Areas
Barra del Colorado (mixed)
Corredor fronterizo (state)
Maquenque (mixed)
Limits of the Study Area
Border Road Nº 1856
Limits of Conservation Areas (SINAC)
CENTRO CIENTIFICO TROPICAL
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Data base from the GRUAS II Project
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Ph.D. Guisselle Monge Arias
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Meters

The corridor initiative is promoted by the Local Council of the San Juan-La Selva Biological Corridor with support from the Tropical Science Center through its administrative and logistical resources. The Local Council is integrated by a number of state and civil society institutional representatives (Chassot and Monge, 2002).

5.1.1.2 Life Zones

Two life zones are found within the study area: the very humid basal transition pre-montane forest and the very humid tropical forest (see Map 9), with annual rainfall that varies between 2.300 and 2.800 mm.. Furthermore, there is an extended rainy period of 10 months on average, and an average temperature of 27 º C with some variability during the months of April and December, with maximum temperatures of 29 º C (Holdridge 1987).

The pre-montane very humid forest is the life zone that covers the western part of the study area. This forest is of low to median height, semi-perenifoliar, with two to three strata, with some canopy species such as oaks (Quercus), with short stems that divide into ascending branches, long, heavy and twisted, that end in broad umbrella-like tops. The soil is covered by ferns, begonias, araceas and creeper plants, and by a thick cover of mantle in a state of decomposition.

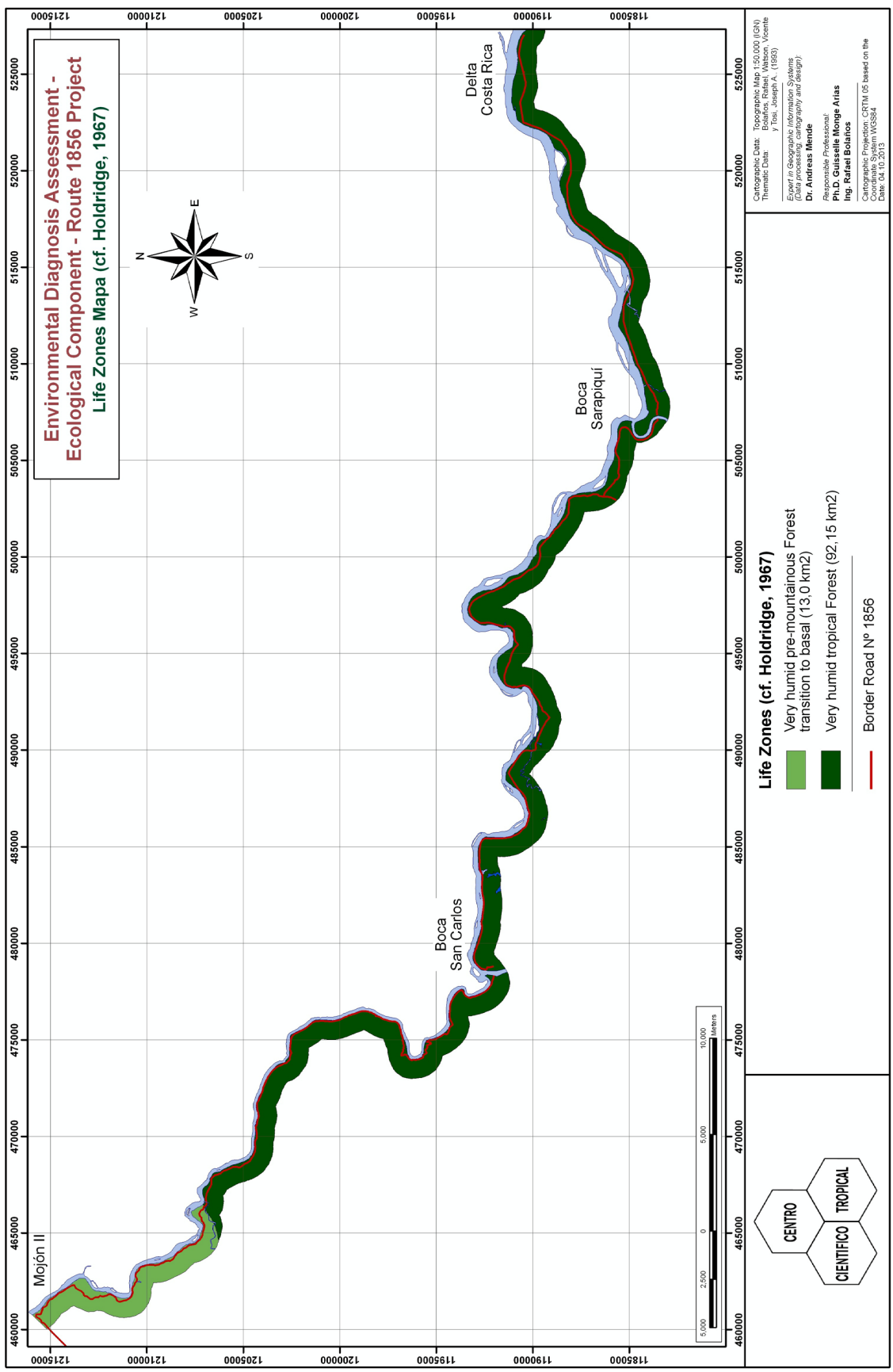
The more common epiphytes, bromeliads and ferns, are small. A thin layer of fern grows on tree trunks and herbaceous vines are common on the ground surface or near the ground, as well as tree vines, which are thick and very common (Holdridge 1987).

The very humid tropical forest is the most representative life zone in Northern Costa Rica where it covers 61% of the territory in the lowlands of Sarapiquí and San Carlos. It is the life zone that provides the main connecting habitat between the southern part of the Atlantic watershed of Nicaragua and the Central Volcanic Range of Costa Rica. It is characterized by very high rainfall.

Canopy trees generally grow to 30-40 meters in height, and have round broad tops and trunks that are relatively short and smooth. Tree buttress wings are common but small. The cortex is for the most part of grey or brown colour, of moderate thickness and flaky or containing fissures and the leaves often form bunches at the extreme end of the branches. There are epiphytes but these are not very conspicuous. Herbaceous climbing vines are abundant and most of the trees are covered by a dense layer of moss (Holdridge 1987).

Central American flora and fauna reflect in their diversity and richness of species a characteristic interphase between the biotas of the Neo-tropical zone of South America and the Neo-Artic North America. The biological diversity present in the study area is exceptionally diverse, reflecting the general bio-geographic situation ofCentral America and as a consequence of strong altitudinal differences ranging between 30 and 3,000 meters above sea level (temperature gradients); different rainfall patterns and variations in the type of soils (Chassot et al. 2005).

Possibly, the San Juan-La Selva Corridor is the biological corridor with the greatest biological diversity in Central America, with an important number of endemic plant species. The climate in most of the northern part of Costa Rica is that of the Atlantic watershed. It is generally determined by atmospheric systems of large magnitude, as are the Inter-tropical Convergence Zone (ICZ), the Eastern Waves and the modified cold fronts from the North, which are waves that create instability (Chassot et al., 2005).


Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Life Zones Mapa (cf. Holdridge, 1967)
Mojón II
Boca San Carlos
Boca Sarapiquí
Delta Costa Rica
N
E
S
W
Life Zones (cf. Holdridge, 1967)
Very humid pre-mountainous Forest transition to basal (13,0 km2)
Very humid tropical Forest (92,15 km2)
Border Road Nº 1856
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Bolaños, Rafael, Watson, Vicente y Tosi, Joseph A., (1993)
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Ph.D. Guisselle Monge Arias
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO
CIENTIFICO
TROPICAL
5,000 2,500 0 5,000 10,000 Meters

The ICZ determines to a great extent the general climate of the country during the period of May to December, particularly on the Pacific Watershed, creating frequent and abundant rains. The general macro-climate of the Northern Caribbean is humid tropical to very humid, characterized mainly by rainfall throughout the year, without a well-defined dry season which only lasts with a few weeks. More specifically, for the regions closer to the northern border, there are local effects such as the wind breezes that move towards and away from the San Juan River (Chassot *et. al.* 2005).

5.1.1.2.1 Project Area Bioclimate

According to the life zones map of Costa Rica (Bolaños and Watson, 1993) and observing the relationship between the existing vegetation with ecosystems present at the site, two life zones are found along the extension of the project area. Most of the Route extension analysed (92 km.²) belongs in the life zone category of Very Humid Tropical Forest (between Infiernito River and the Delta), while some 13 km.² located between Border Marker 2 and Infiernito River are located within the Very Humid Pre-montane transition to Basal Forest, which corresponds with a less rainy bio-climate.

These life zones belong to the Tropical Latitudinal Region, and to the Province of Perhumid Humidity (very humid). In consequence both zones are very humid, with a pluvial precipitation rate that exceeds more than double the evapotranspiration potential of the area. These bio-climatic characteristics denote that the expected natural vegetation for these conditions corresponds with dense forests, exuberant and diverse in species, under natural unperturbed conditions.

Climatically, it means that the life zone known as Very Humid Pre-montane transition to Basal Forest has an annual median inferior precipitation rate of 4000 mm. (within the study area between 3500 and 4000 mm., approximately), while in the very humid tropical forest there is greater precipitation, with an annual median superior rate of 4000 mm. which increases gradually from West to East, reaching 5000 mm. annually in the area of Kilometer 0 of the Route. However, based on field observations, it is possible to conclude that the section between Infiernito river and the mouth of the San Carlos river shows and irregular precipitation pattern with increases and reductions according to the local physiography.

It is a well known fact that the areas located within the Very Humid Tropical Forest life zone are very restrictive environments for the establishment of many different activities of land use. They are fragile areas which at the same time are rich in bio-diversity. The median annual bio-temperature along the Route shows little variation, given the minimal altimetric fluctuation. For this area of the Project, this factor varies between 24 and 25 º C annually.

5.1.1.3 Natural Associations and Land Cover

Costa Rica is one of the 20 countries in the world with the highest biodiversity, with more than 10,000 known species of plants. This number places the country in an estimated 12th position in terms of the absolute number of species of plants. Likewise, there are many diverse natural associations present in the country (Janzen 1983).

In the study area of Route 1856, various ecosystems or ecological associations are known, among them: forest associations (secondary, primary and intervened forests), wetland systems, riparian systems and “yolillo” palm associations.

In the last years, and because of the extension of agricultural lands, many of the primary forest ecosystems in the border territory have been altered and/or destructed and later converted into secondary forests. Even so, these forests present a high vegetal diversity.

Regarding the wetland systems, there exist in the area an important quantity of rivers, creeks, channel and lagoons where a typical vegetation of lacustrine and palustrine wetlands is found. The wetlands are ecosystems that depend on aquatic regimes, natural or artificial, permanent or temporal, lentic or lotic, fresh or salt water, including marine extensions up to the posterior limit of marine fanerogams or corral reefs, or, in their absence, up to six meters of depth in low tide (CCT 2008).

Lacustrine systems are aquatic habitats that present the following general characteristics: they are located in topographical depressions or in conditions of natural or artificially dammed drainage, with a depth of less than 2 meters, which may contain vegetation such as emerging, floating plants, moss and lichens, and the water is fresh. On the other hand, the palustrine system includes all wetlands of interior lands with the following characteristics: they may have plant cover or not (such as is the case with Yolillales), the vegetation may show a dominance of trees, bushes and busy vegetation, and/or emergent vegetation, moss and lichens; the depth levels in depressions do not exceed two meters and the water is fresh water with some sediment in suspension. Swamps proliferate among them, with herbal and gramineal vegetation, marshes with palm vegetation ("Yolillales") and swamps of flooded forests (Bravo and Ocampo 1993).

Finally, the area has aquatic and river margin environments that drain the bodies of water and keep water in slow or rapid motion and which can be characterized as fluvial corridors. The main ones are the Remolino Grande lagoon (lacustrine wetland), Maquenque lagoon (palustrine wetland), Tambor lagoon (also Tamborcito, a lacustrine wetland), Canacas lagoon (palustrine) and Colpachí lagoon (lacustrine); all of them of biological, scenic and eco-touristic interest. The majority of them connect with the San Juan River through the Cureña, Cureñita, Tamborcito and Colpachí channels. The water in these environments is mildly turbid with light penetration of no more than one meter in apparently meso-trophic state due to plant decomposition (Mata, 2005).

Riparian eco-systems are characterized by a marked presence of species such as the "sotacaballo" (*Zygia confusa*), "gavilan" (*Pentaclethra macroloba*), "poponjoche" (*Pachira acuatica*), and "Caobilla" (*Carapa guianensis*). The following pioneering species are also common: "guarumo" (*Cecropia spp.*) and "balsa" (*Ochroma pyramidale*). In associations or eco-systems known as "Yolillales", the dominant plant is the "Yolillo" palm tree (*Raphia taedigera*), (CCT 2008).

5.1.1.3.1 Characterization

The border strip that limits with the San Juan River, specially its right margin, has been subjected to alteration in forest areas, and small isolated human settlements have been established for many decades, in part due to the presence of a navigable river. According to Moreno and Muller (2007), and Chassot (2010), the penetration of settlers in this area began in mid-19th Century, from both bordering countries. Moreno and Muller state that " the confluence of Nicaraguan and Costa Rican population opened up the way for exchange and development of practices for the extraction of rubber, wood, and "raicilla", with lumber being one of the main natural resources extracted in the region."

That is the reason why the forests along the San Juan River were for a long time object of selective extraction of some of its wood, or cut down in order to develop pastures for cattle or subsistence agriculture. The presence of secondary forests with several decades of growth indicates that such sites have been abandoned after a few years of use. On the right margin of

the river, due to the ease of extraction of products through fluvial means, this process occurred repeatedly, unlike in the inner territory south of the river, where wood extraction was connected to the penetration of roads from the interior of the country starting in the final two decades of the 20th Century.

In that regard, the organization Friends of the Earth (Amigos de la Tierra) (2000), indicates that in this border territory many families settled a long time ago: "many have been in possession of these lands for over 60 years and they have established farms, edifications and roads."

Ever since the 1980s the push of the agricultural frontier from the northern regions of the country is beginning to transform this border forest area into pecuarian productive units mainly, despite the difficult access, transforming slowly the diverse natural forest eco-system into agro-pecuarian activities.

Nevertheless, not all sites in the area are adequate for agro-pecuarian activities, so that in some areas the process of forest substitution did not proceed or actually fell back. Presently, a border zone is observable with areas where agro-pecuarian activities are dominant and other areas where the natural forest eco-system dominates the landscape, the latter conditioned by the less than favourable topographic conditions and fertility of the land.

In general terms, along the path designated for Route 1856 flat or slightly undulating terrain is dominant, although there are short stretches where these undulations are accompanied by local steep slopes with solid ground that use to be covered, and may still be covered, by forests with significant biodiversity.

On the other hand, towards the eastern sector of the Route, flat or slightly concave roads are dominant, and in some sections these contain wetlands. These wetlands are small compared with those located towards the east of the area under study. However, because of their small size, they are more open to alterations and transformations and are of great importance for the capacity to contribute to biological diversification due to their distinct bio-physical conditions.

5.1.1.4 Current Plant Cover by Natural Association

The lowlands of the Northern Caribbean territory of Costa Rica constitute one of the priority sites for biodiversity conservation in Mesoamerica. However, the landscape has suffered a strong process of fragmentation that threatens connectivity among natural protected areas in Costa Rica and the southeast of Nicaragua (Chassot and Monge 2006).

Wetlands are under strong threat worldwide due to replacement activities and modification of the landscape, despite the fact that they are determinant units in the ecosystems that regulate water dynamics. On the other hand, wetlands are the home of a large quantity of flora and fauna, especially birds that use these environments as part of their biological and ecological requirements and as such can serve as indicators of the quality of eco-systems (CCT 2008).

In 1992, COSEFORMA estimated that only 5% of the original forest in the region remained intact; forest extractive activities during the last decade have significantly reduced this percentage. The present use of the land in this area consists of a variety of non sustainable uses of the forests, alternating with cattle-raising and pineapple production, palm tree and root crops in small scale. Some of the land cover types present in the area (Chassot and Monge, 2006) are:

a. ***High Altered Forests:*** It has poorly defined strata. Some common species are "caobilla" (Carapa guianensis), "roble coral" (*Terminalia amazonica*), "jicaro" (*Lecythys ampla*), "manú" (*Minquartia guianensis*), "fruta dorada" (*Virola hoshnyi*), "pilón" (*Hieronyma*

oblonga) and “areno” (*Qualea paraensis*); there are few palm trees in the understory layer.

b. ***Riparian Forest:*** This forest is characteristic of the region with very large trees that border the channels that connect with the lagoons. Among these, the following stand out: “Cativo” (*Prioria copaifera*), which forms pure clusters mainly at the entrance to Tambor Channel, accompanied by “caobilla” (*Carapa guianensis*) and Ficus. The lowest layer in this type of forest contains large numbers of Geonoma palms, as well as Heliconia; the canopy has a large quantity of bromeliads and orchids.

c. ***Yolillo patches:*** Raphia taedigerra and Coroso oleifera, known as “Yolillo” form large patches that may extend for several hectares and can be associated with “gavilán” (*Pentaclethra macroloba*) and “sangrillo” (*Pterocarpus officinalis*).

d. ***Lagoon vegetation:*** Aquatic plants found in lagoons include *Hymenocallis litoralis* (Amarillidaceae), *Urospata grandis* (Araceae), *Aeschunomene sensitiva* (Pailionacaeae), *Nepsera acuatica* (Melastomatacea), *Ludwigia sedoides* (Onagaraceae) and Ciperaceae.

5.1.1.4.1 Recognized Natural Associations

Along the study area, studies recognize the presence of various ecosystems and ecological associations, particularly some types of wetlands, whereas forest associations in inland areas are not recognized and are generally known simply as forests.

Within the wetland eco-systems in this area, the TSC (2008) points to the Maquenque lagoon (palustrine wetland) and the Remolinito Grande lagoon (lacustrine wetland). The Maquenque lagoon has been greatly altered by human activity and is being used mostly as pasture lands, it has almost no permanent water surface, only when it floods due to heavy rainfall.

Several Yolillo associations are identified which are palustrine wetlands without permanent water surfaces, covered by a particular type of palm tree (Raphia taedigera). In addition, in the area close to the direct impact area of the project (2 to 6 km. from the Route), other important wetlands are located such as the Tambor and Colpachí lagoons, as well as the Canacas Yolillo patch. These wetlands, although permanently flooded, are shallow, reaching at most a depth of 2.5 meters.

Of the different natural eco-systems identified partially within the area of Route 1856, the Maquenque Mixed National Wildlife Refuge has been subjected to the most research and analysis. In 2008 the TSC described the importance of the sector as follows: The Maquenque Refuge contains a series of complex lagoons that represent the wetlands of the region and are an important part of the hydrological system, characterized by the presence of three great rivers: San Juan, San Carlos and Sarapiquí rivers, which create natural limits to a large section of the protected area, underscoring the importance of the conservation of a unique eco-system that protects a large number of species in danger or threatened by adverse effects that in many cases are generated by human activities.”

Also, in the management plan proposed for the border biological corridor, Amigos de la Tierra (2000) points among the ecosystems of national importance, apart from wetlands and yolillales, to the less altered tropical forests, in reference to the forest association found between the Tiricias and Cureña sector, as the most important remnant forests in the Huetar Norte region, considered the ecosystems with the highest biodiversity index in the country (up to 140 species of trees per hectare).

The TSC (2008) states that the area of the study has an estimated 354 species of trees, in addition to 107 species of vines and 380 species of epiphytes. This information refers to the area of the Maquenque Refuge, which covers a area of the Route 1856 study, but stretches extensively to the South of the border.

Chart3: Natural Associations recognized in the study area..

Association or Ecosystem	*Presence in the DIA*	*Presence in the IIA*
Palustrine wetland	-	✓
Lacustrine wetland	Limited	✓
Yolillal	✓	✓
Riverine Systems	✓	✓
Forest associations (4 types)	✓	✓

Source: Centro Científico Tropical, 2008.

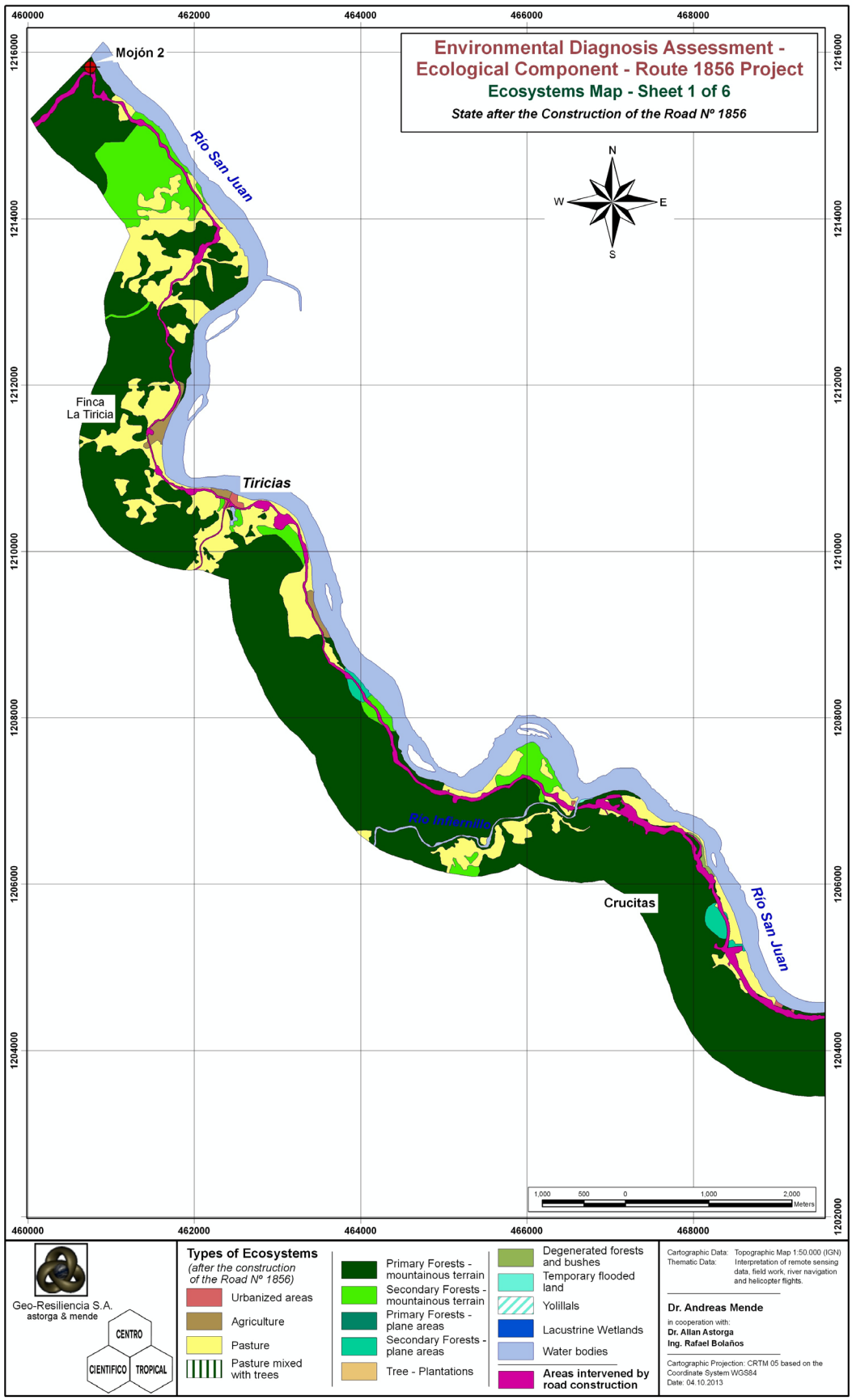
In the case of forest associations, the TSC (1996) classifies three types of associations for a region close to Route 1856: the flat lands primary forest, the primary forest on slopes, and the secondary forest. These forest associations show important differences in their floristic composition, diversity of species and bio-mass volume, among other aspects.

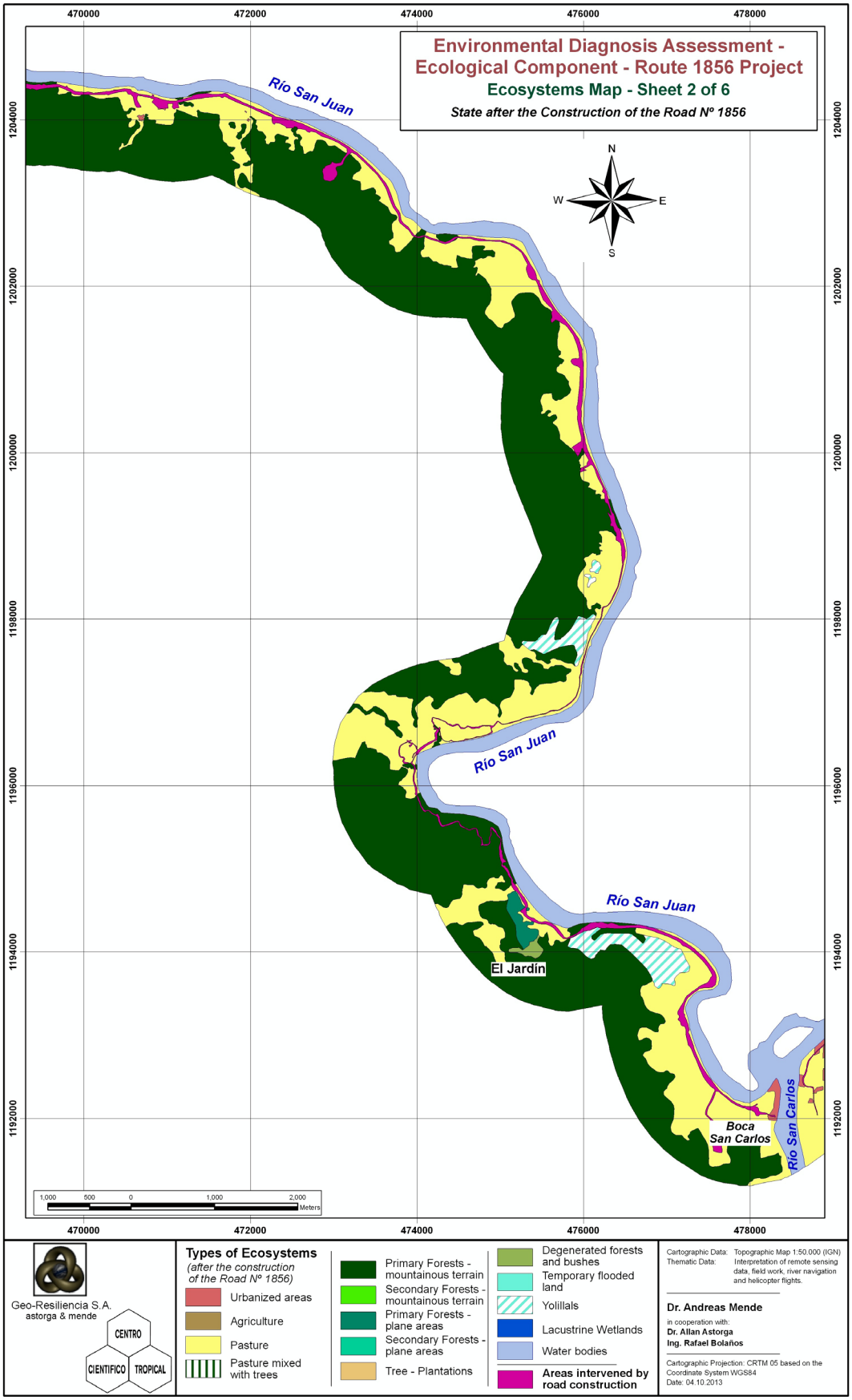
5.1.1.4.2 Plant Cover by Natural Association

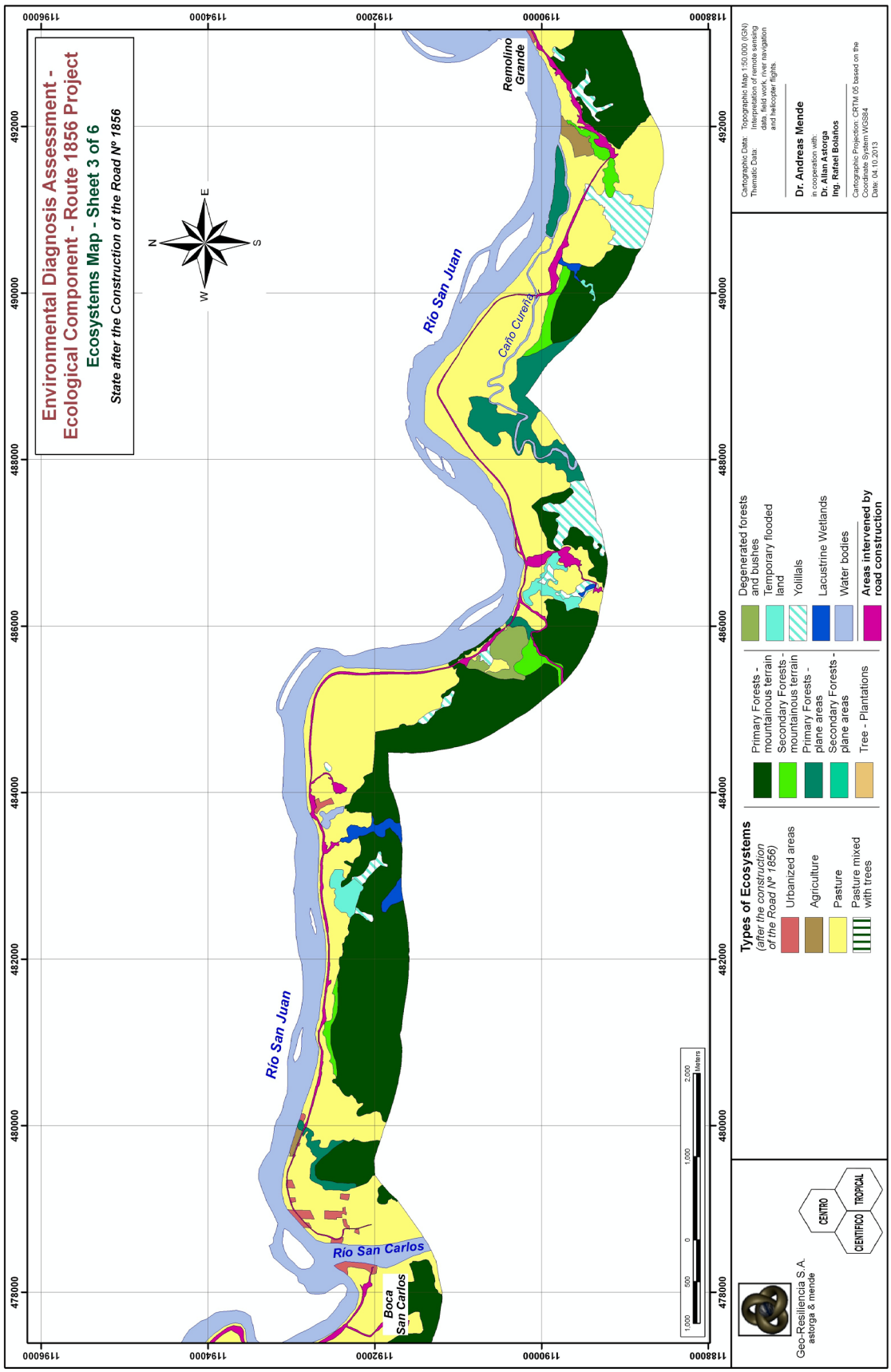
At the time of this study, no quantitative data was found on the natural associations existing along Route 1856. Due to the latter, the study conducted a classification effort of the main associations present in the area of direct influence (DIA), according to some studies that offered partial numbers. The methodology used was as follows.

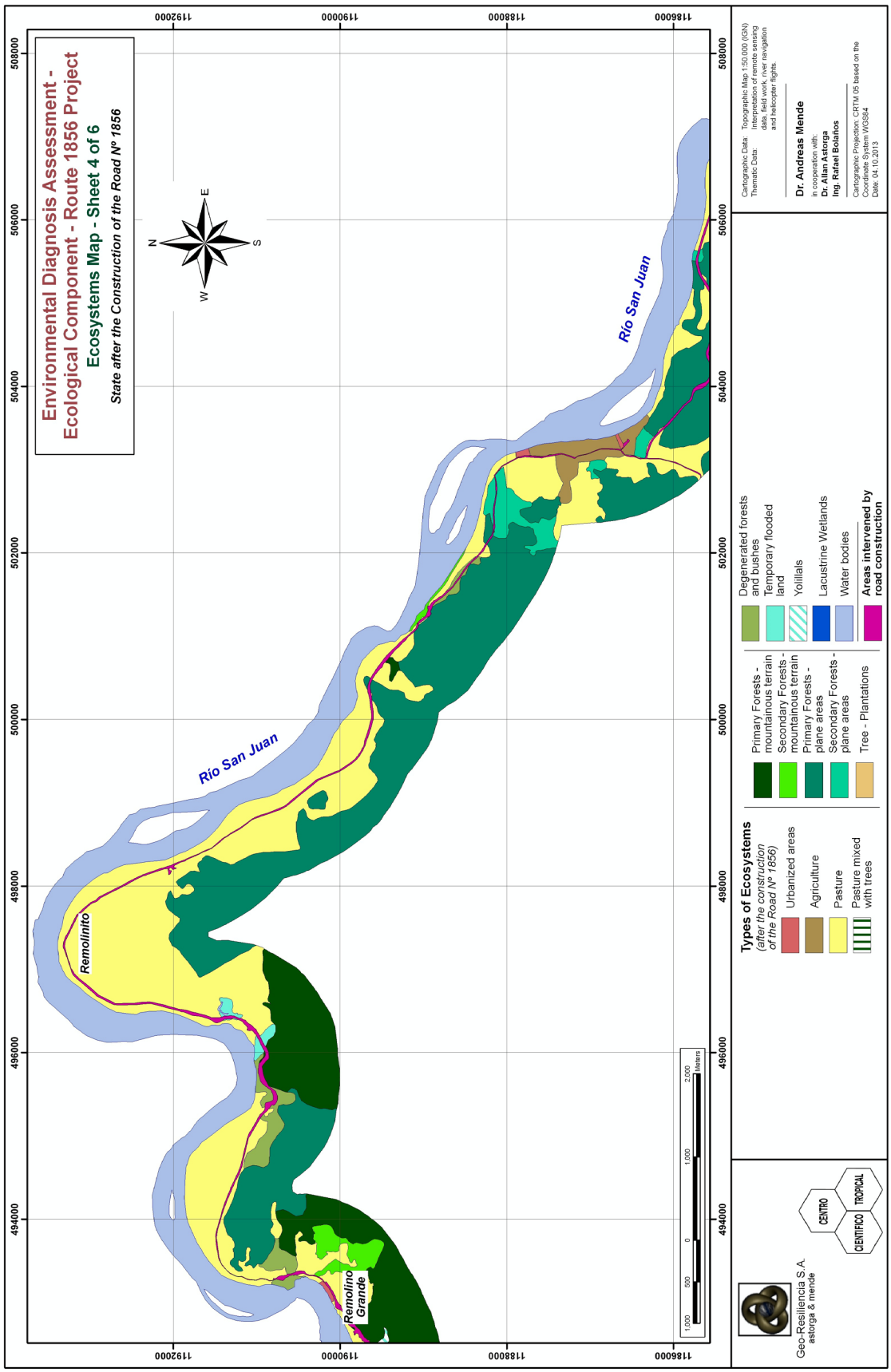
5.1.1.4.3 Description of natural associations and its indicator species

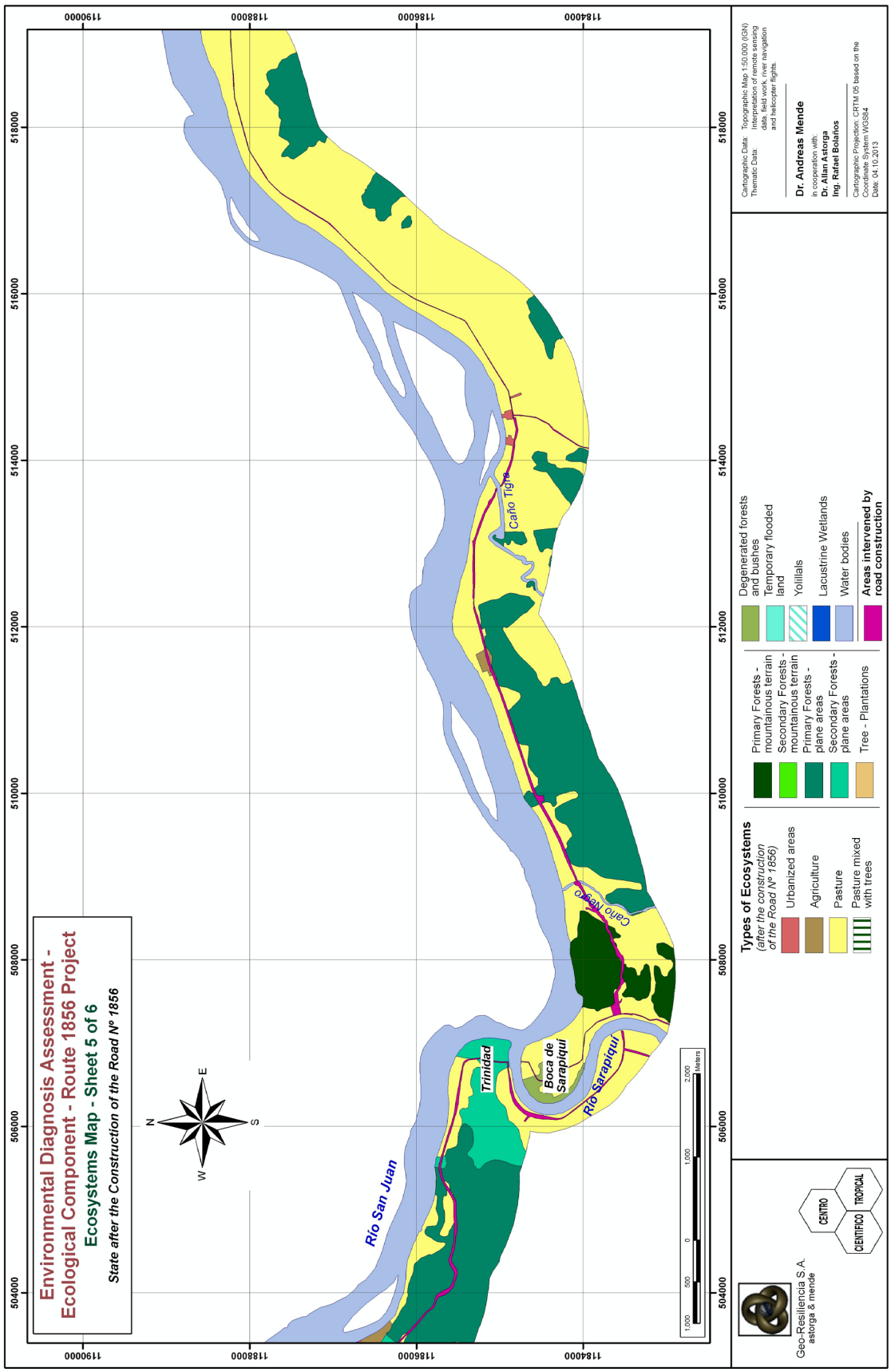
The different natural associations are divided into primary forest on sloping terrain, secondary forest on slopes, primary forests on flat lands or plains, and secondary flat lands (See Maps 10, 11, 12, 13, 14, 15 and Chart 4). It is important to point to the fact that 47% of the DIA shows cover that is not natural, that is, it is altered lands, used basically for cattle pastures since many years ago.


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Ecosystems Map - Sheet 1 of 6
State after the Construction of the Road Nº 1856
460000
462000
464000
466000
468000
1216000
1214000
1212000
1210000
1208000
1206000
1204000
1202000
N
W
E
S
Mojón 2
Río San Juan
Finca La Tiricia
Tiricias
Río Infiernillo
Crucitas
Río San Juan
1,000 500 0 1,000 2,000 Meters
Geo-Resiliencia S.A.
astorga & mende
CENTRO CIENTIFICO TROPICAL
Types of Ecosystems
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Ecosystems Map - Sheet 2 of 6
State after the Construction of the Road Nº 1856
Río San Juan
Río San Juan
Río San Juan
El Jardín
Boca San Carlos
Río San Carlos
N
W
E
S
470000
472000
474000
476000
478000
1204000
1202000
1200000
1198000
1196000
1194000
1192000
1,000 500 0 1,000 2,000 Meters
Geo-Resiliencia S.A.
astorga & mende
CENTRO CIENTIFICO TROPICAL
Types of Ecosystems
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Ecosystems Map - Sheet 3 of 6
State after the Construction of the Road Nº 1856
Río San Juan
Río San Carlos
Boca San Carlos
Remolino Grande
Caño Cureña
Río San Juan
Types of Ecosystems (after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
in cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Geo-Resiliencia S.A.
astorga & mende
CENTRO
CIENTIFICO
TROPICAL
Meters


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Ecosystems Map - Sheet 4 of 6
State after the Construction of the Road Nº 1856
Río San Juan
Río San Juan
Remolinito
Remolino Grande
Types of Ecosystems (after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
In cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Geo-Resiliencia S.A.
astorga & mende
CIENTIFICO
CENTRO
TROPICAL


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Ecosystems Map - Sheet 5 of 6
State after the Construction of the Road Nº 1856
Río San Juan
Trinidad
Boca de Sarapiqui
Río Sarapiqui
Caño Negro
Caño Tigre
Types of Ecosystems (after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
In cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Geo-Resiliencia S.A.
astorga & mende
CIENTIFICO
CENTRO
TROPICAL
N
S
E
W
Meters

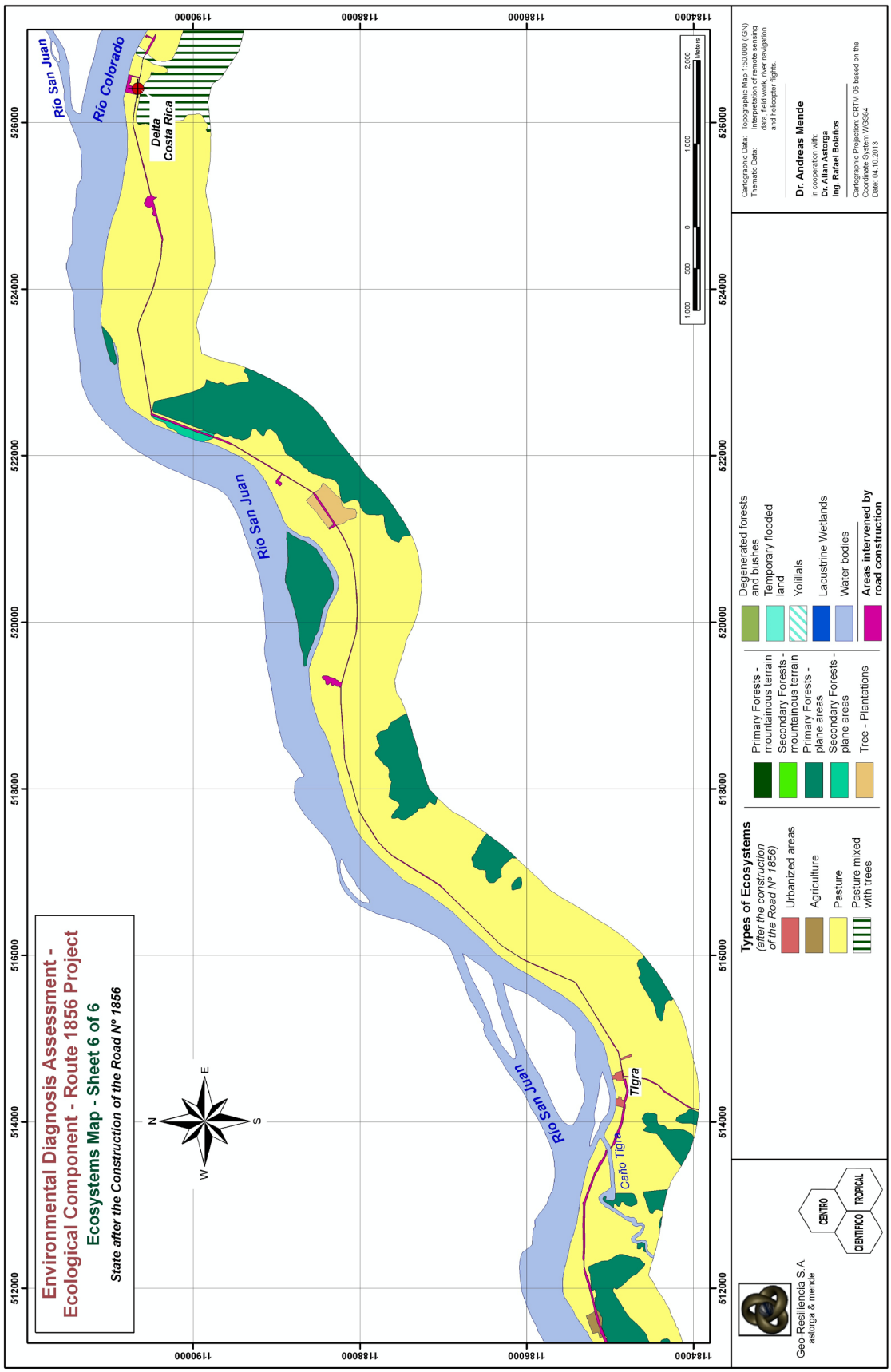

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Ecosystems Map - Sheet 6 of 6
State after the Construction of the Road Nº 1856
Río San Juan
Río Colorado
Delta Costa Rica
Río San Juan
Río San Juan
Caño Tigra
Tigra
N
S
E
W
512000
514000
516000
518000
520000
522000
524000
526000
1184000
1186000
1188000
1190000
1,000 500 0 1,000 2,000 Meters
Types of Ecosystems
(after the construction of the Road Nº 1856)
Urbanized areas
Agriculture
Pasture
Pasture mixed with trees
Primary Forests - mountainous terrain
Secondary Forests - mountainous terrain
Primary Forests - plane areas
Secondary Forests - plane areas
Tree - Plantations
Degenerated forests and bushes
Temporary flooded land
Yolillals
Lacustrine Wetlands
Water bodies
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
In cooperation with:
Dr. Allan Astorga
Ing. Rafael Bolaños
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
Geo-Resiliencia S.A.
astorga & mende
CIENTIFICO
CENTRO
TROPICAL

Chart4: Area occupied by natural assocaitions recognized in the DIA.

Natural Association	Area in ha	Proportion (%)
Primary forest on slopes	3.525,2	33,7
Secondary forest on slopes	202,0	1,9
Primary forest on plains	1.524,5	14,6
Secondary forest on plains	134,7	1,3
Yolillalo patch	149,7	1,4
Lacustrine Wetland	17,9	0,2
Palustrine Wetland	0,0	0,0
Altered Areas	4.921,3	47,0
Total	**10.475,2**	**100,0**

Source: Own Autorship.

a. Yolillo patch (Yolillal)

This ecosystem evolves on flat or concave flat terrain, which remains almost permanently flooded. It is characterized by homogeneous floristic composition, where the dominant species is the Yolillo palm (*Raphia taedigera*) although in the less flooded areas are often found other species such as the Corozo palm (*Coroso oleifera*) and trees such as the "Gavilan" (*Pentaclethra macroloba*) and "Sangrillo" (*Pterocarpus officinalis*). The Yollilo patches are palustrine sytems, but are separated from them because this association does not keep a visible water surface as happens in various of the palustrine wetlands. It is a natural association not found in abundance with the study area (1,4%).

b. Riverine systems

There exist in the area numerous rivers of different dimensions, as well as channels and creeks. It is difficult to characterize arboreal indicator species, or those typical of these wetland ecosystems, because they depend on the characteristics of the terrain located on their margins, so that in the majority of cases, the species are as diverse as the adjoining forests.

Nevertheless, some species are very common along the borders of these ecosystems: "Sotacaballo" (*Zygiua confuse*), "gavilan" (*Pentaclethra macroloba*), "Caobilla" (*Carapa guianensis*), "fruta dorada" (*Virola spp*), and in the eastern sector of the Route is found "Cativo" (*Prioria copaifera*). Also common are pioneering species such as the "guarumo" (*Cecropia spp*) "Jobo" (*Spondias mombin*), "Guabillo" (*Inga spp*), "Chilamate" (*Ficus insipida*) and "Balsa" (*Ochroma pyramidale*).

c. Lacustrine and palustrine wetlands

Both types of natural associations maintain common plant species, due to the fact that they are lakes with a respective water surface. In their surroundings, in the case of lakes, Forestry Law No. 7575 establishes an area of 50 meters in width as a protection zone around the water surface, which in a natural manner constitutes a forest of diverse species.

In the study area, these natural associations are few and occupy only 0,2% of the section analyzed. Arboreal indicator species or species typical of these natural associations depend on the characteristics of the terrain, in such a way that in the majority of cases the species found are as diverse as the surrounding forests. Some of the more common species are found in the following chart:

Chart5: Common or outstanding tree species in palustrine or lacustrine wetlands.

Common Name	Scientific Name	Common Name	Scientific Name
Sota de Suampo	*Zygia confusa*	Aceituno	*Simarouba amara*
Roble Coral	*Terminalia Amazonia*	Croton	*Croton smithianus*
Gavilán	*Pentaclethra macroloba*	Colpachi	*Croton schiedeanus*
Fruta Dorada	*Virola sebifera*	Manga Larga	*Laetia procera*
Pejibayito	*Maranthes panamensis*	Cedrillo	*Tapirira guianensis*
Repollito	*Eschweilera costaricensis*	Fruta dorada	*Virola koschnyi*
Repollito	*Eschweilera panamensis*	Palma Conga	*Welfia regia*
Botarrama	*Vochysia ferruginea*	Tamarindo	*Dialum guianense*
Mouriri	*Mouriri gleasoniana*	Tabacón de Suampo	*Cespedesia macrophylla*
Maquengue Amargo	*Socratea exorrhiza*	Baco	*Couma macrocarpa*
Nace blanco	*Byrsonima crispa*	Cedro María	*Calophyllum brasiliense*
Laurel Muñeco	*Cordia bicolor*	Cucaracho, Chiricano*	*Vantanea barbourii*
Gallinazo	*Jacaranda copaia*	Maquenque	*Swartzia maquenqueana*
Vainillo	*Sthryphnodendron microstachyum*	Miconia	*Miconia punctata*
Guabo	*Inga alba*	Hirtella	*Hirtella media*
Carey*	*Elaeoluma glabrescens*	Casearia	*Casearia arborea*

Source: Centro Científico Tropical. 2008, citing to: Salas, 2007 / *Species with some degree of vulnerability.

d. Forest associations

The forests in this region present a very high floristic diversity, which leads to the dominance of some species in certain areas, depending mainly on physical and climatic factors such as rainfall differences, soil conditions and topography.

In the following paragraphs the different recognized forest associations are described, as well as the common species observed during field work. These are common to various associations but they vary in terms of abundance or dimensions of the trees, so they are presented jointly. Four

distinct types of natural forest associations are described which jointly cover some 51,4% (5,386 hectares) of the DIA.

i. Primary forest on flat lands

This type corresponds to forest associations that evolved over plain or flat terrain and up to slightly undulating terrain (0-5% slope). In some cases these terrains have drainage problems. The forest is tall and dense and its canopy may reach 40 to 45 meters in height. It has less diversity of species as the primary forest found on sloping lands, but its trees have a greater volume equivalent to 150 m³/ha taking into account trees with 30 cm. In DBH height. It contains some 420 trees greater than 10 cm/ha (CCT, 1996).

The same source indicates that at least for this sector the most outstanding species is the yellow almond, which represents 50% of the volume. In similar manner, this species, along with "Tamarindo" and "Caobilla" turn out to be the most common trees. This is an ecosystem that still provides important cover (14,6% of the study area), despite the fact that much land was deforested to introduce cattle grazing.

ii. Primary forest on sloping terrain

These forest associations are locate on hillsides and sloping terrain, with slopes of 5 to 80%. This is the most abundant natural association since it occupies more than one-third of the total area analyzed (see Chart 2.). Its basic character is one of well-drained soils and low fertility with clay texture soils and very high susceptibility to hydric erosion.

The forest is characterized by a medium height, with a canopy that reaches 35 to 40 meters, is quite dense and very diverse in tree species. According to CCT (1996) this type of forest when not altered contains some 115 me³ /ha (30 cm. in DBH), with some 660 trees per hectare, at 10 cm.DBH). The most common species is the "tamarindo", while the largest in volume is the "almendro Amarillo". Palm trees are very abundant.

However, the volume, number of species and trees found in this type of forest is drastically reduced when it has been exploited for lumber, with only half of the trees reaching girths beyond 10 cm..

iii. Secondary forest on flat lands

These associations are forests of secondary growth which have evolved over flat lands, or almost flat, in conditions similar to those described for primary forests. Their development, density, height and species are very variable because they depend on the years of forest recovery. Observations in the area suggest that these forests are few and young (5 to 20 years) with tree heights that do not go beyond 20 meters. This study quantified only 135 hectares of this type of association.

No information was obtained on the number of trees per hectare for this association, but in relation to the primary forest, it is estimated that this forest is less dense than the secondary forest on sloping terrain, with some 350-500 trees/ha with DBH greater than 10 cm.

iv. Secondary forest on sloping terrain

Much like the previous type of forest, this ecosystem is very variable in structure and composition, but slightly more abundant (1.9%) than the secondary forest on flat land with respect to area, and in some cases there are older units observable where it is possible to find trees reaching 30 meters in height and approximately 30 years old.

These forests are dense, with up to 600 trees/ha (thicker than 10 cm. in DHB) and they also display an important amount of tree species, depending on age and development.

Chart6: Common tree species in forest associations.

Common Name	Scientific Name	Common Name	Scientific Name
Almendro amarillo	*Dipteryx panamensis*	Aceituno*	*Simarouba amara*
Roble Coral	*Terminalia Amazonia*	Algodoncillo*	*Croton smithianus*
Gavilán	*Pentaclethra macroloba*	Pilón	Hieronyma oblonga
Fruta Dorada	*Virola spp*	Manga Larga*	*Laetia procera*
Almendro papayo	*Lecythis ampla*	Cedrillo	*Tapirira guianensis*
Caobilla	*Carapa guianensis*	Sangrillo	*Pterocarpus officinales*
Tamarindo	*Dialium guianense*	Palma Conga	*Welfia regia*
Botarrama	*Vochysia ferruginea*	Chaperno	*Lonchocarpus sp*
Ceiba	*Ceiba pentandra*	Tabacón	*Cespedesia macrophylla*
Palmito Amargo	*Socratea exorrhiza*	Chilamate	*Ficus insipida*
Cebo	*Vochysia guatemalensis*	Cedro María	*Calophyllum brasiliense*
Botarrama	*Vochysia ferruginea*	Anonillo*	*Rollinia microsepala*
Gallinazo*	*Jacaranda copaia*	Chumico	*Pouruma aspera*
Vainillo	*Sthryphnodendron microstachyum*	Manga larga blanco*	*Casearia arborea*
Guabo	*Inga alba*	Guanacaste blanco	*Enterolobium schomburgkii*
Escobo	*Terminalia bucidoides*	Peine de mico	*Apeiba membranacea*
Guácimo colorado	*Luehea seemannii*	Ajillo	*Balizia elegans*
Guarumo*	*Cecropia spp*	Balsa*	*Ochroma pyramidale*

Source: field observations, current study. / *: most abundant species in secondary forests

5.1.1.5 Indicator species by natural ecosystem.

As a result of deforestation during the last decades, the disappearance of natural cover, which implies the disappearance of habitats, has led to the decrease in number of many animal and plant species, among them species of high commercial value for the lumber industry, including important seed trees such as the mountain almond (*Dipteryx panamensis*) (Chassot *et al.* 2001)

Along the path of Route 1856 can be found complexly related wetlands associated with the lower watershed fo the San Juan River: Tamborcito, Tambor, Maquenque, Remolino Grande and Colpachí wetlands. These contain a large quantity of aquatic plant species as well as birds commonly found in wetlands such as the "jabirú" (*Jabiru mycteria*). The vegetation in these lagoons is very valuable since it has a species composition that is only found in Caño Negro. These wetlands are the habitat of fish and mammals such as "gaspar" (*Atractosteus tropicus*) and the Manatee or Sea Cow (*Trichechus manatus*), both of them endangered species. In addition to the lagoons, "yolillo" patches are found along the Route which are often subjected to burning and drainage by human actors (Monge *et al.* 2002).

Some indicator species of the natural ecosystem described are:

a. ***Great Green Macaw:*** this region is the priority nesting area for the Great Green Macaw (*Ara ambiguus*) (Powell *et al.* 1999) and it is key to the survival of the species, included in the CITES Appendix I.

b. ***Manatee:*** *Trichechus manatus* has been observed in the wetlands by farmers throughout the region, who are familiar with the sites where this species plays and reproduces in the Tambor lagoon. This species is also found in the river bottom grasses of San Juan River.

c. ***Gaspar:*** *Atractosteus tropicus* is a living fossil that has a natural breeding ground in the lagoons system of the Maquenque Refuge which empties in San Juan River.

d. ***Jaguar:*** *Panthera onca* has been observed by neighbors in the region and its tracks are commonly found specially in the neighbourhood of the Tamborcito and La Cureña mountains. Frequently, there are reports of cattle being depredated specially along the Border Corridor. Local residents have observed jaguars crossing the San Juan River into the Indio-Maiz Biological Reserve.

e. ***Almendro:*** *Dipteryx panamensis* produces food for many species, among them the Great Green Macaw, a species that depends on this tree for nourishment (80%), as well as nesting (90%).

f. ***Pinillo:*** *Podocarpus guatemalensis* is considered a threatened species. It is represented by a number of specimens of great size which can be found in the forested hillsides close to the Tambor lagoons.

5.1.1.6 Endemic species with reduced or threatened populations.

The current crisis that threatens species with extinction is born with colonization and occupation of territories by human beings, who create forest fragmentation as one of the greatest negative impacts. In the southeastern part of Nicaragua and the northern zone of Costa Rica, forest fragmentation into patches, is a serious threat to ecological connectivity as well as to the genetic quality of biodiversity (Chassot *et. al.* 2001, Chassot *et. al.* 2002, Chassot et. al. 2006, Monge *et. al.* 2000). Many species of flora and fauna depend on the conditions of these forest remnants, among them the Great Green Macaw (*Ara ambiguus*).The following are among the representative emblematic species of the flora and fauna found in the study area:

Ara ambiguus

The Great Green Macaw, *Ara ambiguus,* is the second largest psitacid in the New World. Its distribution is limited to low humid lands, mainly the forests of the Atlantic coast from Honduras all the way to Colombia, and an isolated Pacific population in Guayaquil, Ecuador. It is

recognized internationally as a threatened species, and in Costa Rica it is included in Appendix I of the Convention on Commerce of Endangered Species (CITES).

Its historical reproductive area in Costa Rica has been reduced by 90%, mainly due to uncontrolled lumber extraction and deforestation to introduce pasture lands during the second half of the 20th Century, and is currently limited to the northern region of Costa Rica, with greatest concentration in the area between the San Carlos, San Juan, Sarapiquí rivers, and the northern slopes of the Central Volcanic Range.

The Bi-National El Castillo-San Juan-La Selva Biological Corridor (Nicaragua-Costa Rica) constitutes the last viable habitat of less developed lands that can maintain the Great Green Macaw and a unique biodiversity area, by connecting more than twenty protected areas (Monge *et al.* 2003).

Dipteryx panamensis

The mountain almond *Dipteryx panamensis* is a Fabacea (Leguminosae) whose distribution is limited to the lower parts of the Atlantic Coast of Nicaragua (South), Costa Rica, Panama and Colombia (Flores 1992). This is a tree that rises from the canopy found in humid and very humid forests where the median annual temperature varies between 24º and 30º, and the median annual precipitation is greater than 3500 mm. with elevations between 20 and 1000 meters above sea level (masl).

It is considered to be abundant in the northern region of Costa Rica (Flores 1992). Despite the fact that it is a slow-growth tree in a natural environment, observations show that growth response is greater in forest clearings, in forest borders and in grasslands with important incidence of sunlight. The almendro tree reaches great height and always stands out in the canopy, a condition that the Great Green Macaw uses to its advantage to build its nests in a safe spot (see Map 16) in the wholes left by fallen branches (Flores 1992).

Of the more than 100 known Great Green Macaw nests that are currently potentially active, only 3 of them (3%) are located in the influence area of Route 1856, so that the impact of this project on the Great Green Macaw population is considered irrelevant.

The almendro wood is extremely hard, nevertheless its use was not attractive until the mid 1980s due to its extremely difficult and costly extraction. As new technology led to the development of steel saws with carbon content, and the use of diamond-point saws, these great trees have begun to disappear from the landscape, thanks to the high mechanical resistance and quality of its wood, which have turned the species into a highly priced lumber. The almond tree constitutes 90% of nesting sites of the Great Green Macaw. Likewise, the tree provides 80% of the parrot´s nourishment showing a dependent relationship between the two species: almond-Great Green Macaw (Monge *et al.* 2003; Madriz 2004).

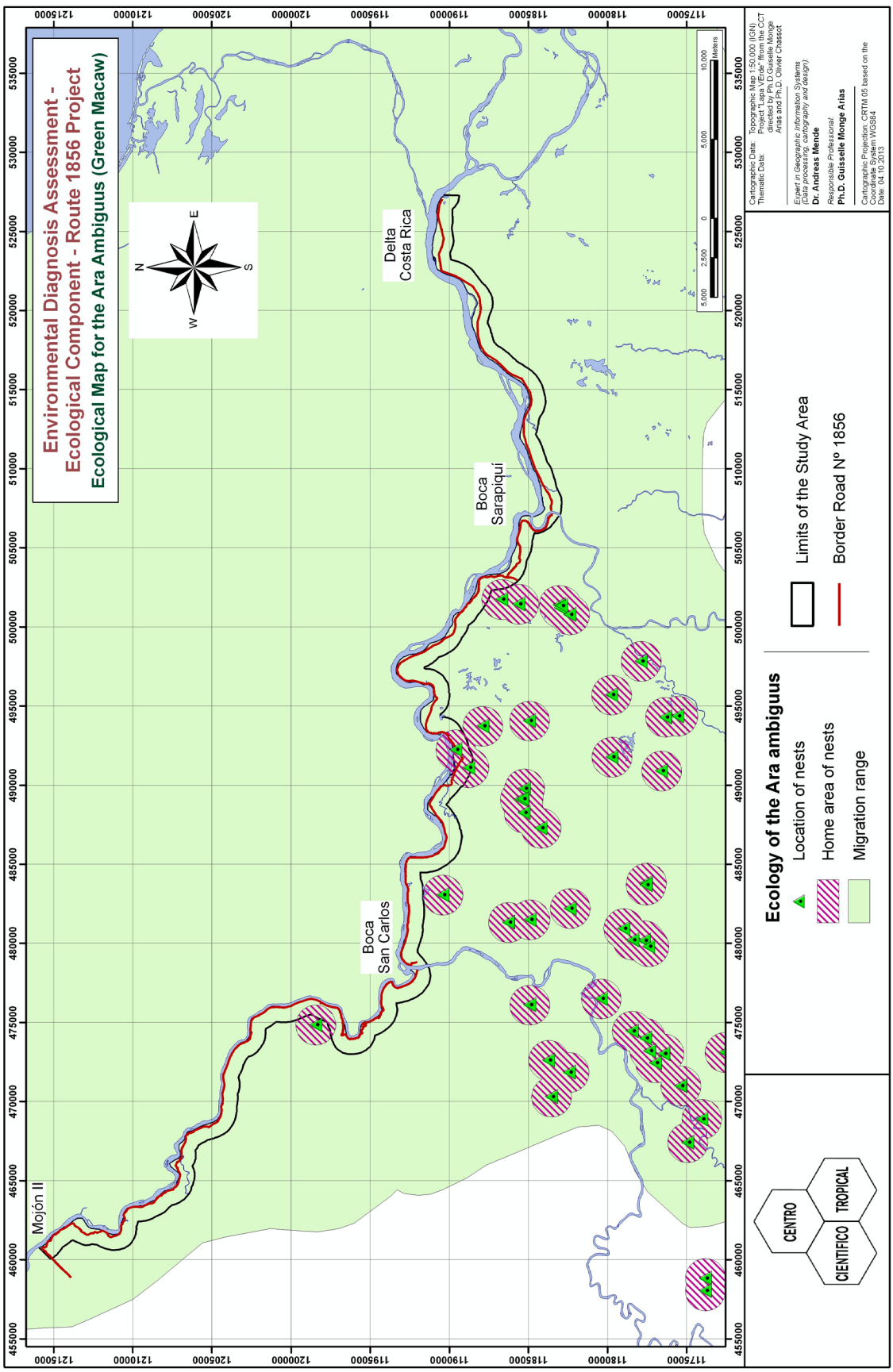

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Ecological Map for the Ara Ambiguus (Green Macaw)
Mojón II
Boca San Carlos
Boca Sarapiquí
Delta Costa Rica
N
S
E
W
0
2,500
5,000
5,000
10,000
Meters
Ecology of the Ara ambiguus
Location of nests
Home area of nests
Migration range
Limits of the Study Area
Border Road Nº 1856
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Project "Lapa Verde" ffrom the CCT directed by Ph.D.Guiselle Monge Arias and Ph.D. Olivier Chassot
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Ph.D. Guiselle Monge Arias
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

Chart7: Main threatened species within the Route 1856 study area.

Class	Common Name	Scientific Name
Mammals	Oso caballo	*Myrmecophaga tridactyla*
	Mono congo	*Alouatta palliata*
	Mono colorado	*Ateles geoffroyi*
	Nutría	*Lutra longicaudis*
	Jaguar	*Panthera onca*
	Manatí	*Trichechus manatus*
	Cariblanco	*Tayassu pecari*
	Danta	*Tapirus bairdii*
Birds	Galán sin ventura	*Jabiru mycteria*
	Águila solitaria	*Harpyhaliaetus solitarius*
	Águila crestada	*Morphnus guianensis*
	Águila arpía	*Harpia harpyja*
	Aguilillo blanco y negro	*Spizastur melanoleucus*
	Cacao	*Daptrius americanus*
	Halcón pechirrufo	*Falco deiroleucus*
	Pato cantil	*Heliornis fulica*
	Lapa verde	*Ara ambiguus*
	Lapa roja	*Ara macao*
	Momoto pico quilla	*Electron carinatum*
Reptiles	Cocodrilo	*Crocodylus acutus*
	Tortuga lagarto	*Chelydra serpentina*
Fishes	Gaspar	*Atractosteus tropicus*

Source: Chassot *et al*. (2005).

a. Mammals

The tapir (*Tapirus bairdii*) and wild pigs persist in extensive flooded forested areas and Yolillo patches. The “tepezcuintle” (*Agouti paca*), the mountain goat (*Mazama americana*) and the “cariblanco” pig (Tayassu tajacu) are common. Manatee (*Trichechus manatus*) and “jabalí” (*Tayassu pecari*) populations have decreased dramatically.The following mammals found in the region are included in Appendix I of CITES: *Alouatta palliate, Ateles geoffroyi, Lutra longicaudis, Panthera onca, Puma concolor, Trichechus manatus,* and *Tapirus bairdii* (see threatened species).

Mammals reported in Appendix II of the CITES list are: *Cebus capucinus, Myrmecophaga tridactyla, Bradypus variegates, Leopardus pardalis, Leopardus wiedii, Herpailurus yaguarondi, Tayassu pecari, Tayassu tajacu.*

b. Birds

The following species in the study area are included in Appendix I of CITES (species that are threatened or that may be affected by commercial interests): *Harpia harpyja, Falco peregrinus, Ara ambiguus, Ara macao*, *Falco deiroleucus, Spizastur melanoleucus, Daptrius americanus, Morphnus guianensis, Jabiru mycteria, Heliornis fulica, Electron carinatum*.

c. Fishes

The region is part of the icthious watershed of the San Juan River. The San Juan watershed, which includes the San Carlos and Sarapiquí rivers, is a diverse and rich area in terms of fresh water fish. This is related to the hydrographic structure where large rivers, streams and lagoons connect to the San Juan River, the Caribbean Ocean and Lake Cocibolca. This explains the presence of the bull shark (*Carcharrinus leucas*), "pargos" (Lutjanidae) and "roncadores" (Haemulidae).

The following are common: poecilides, characids (particularly *Astyanax fasciatus*) and the cyclids, "mojarras" and "guapotes". The poecilides minnows are the most abundants: among them the most common is *Alfaro cultratusy*. "Guapotes" are common (*Ciclasoma doviiy*, *Ciclasoma loiselle*), the "guapote tigre" (C*iclasoma managuense*) and the "vieja" (*Ciclasoma nicaraguense*).

d. Reptiles and amphibians

The following are found in Appendix I of CITES:*Chelidra serpentina*, *Crocodylus acutus*. Appendix II includes*Dendrobates pumilio*, *Dendrobates auratus*and*Phyllobates lugubris*.

e. Flora

According to Friends of the Earth (2000), in the Border Corridor (2 km. wide): "populations of nine species of trees are under threat of extinction, several flora species are threatened, including at least four endemic species". Of these four endemic tree species found along the Corridor, three are reported to be found within the central section of the 1856 Route, although others are not dismissed.

Chart8: Endemic tree species reported for the study area.

Scientific Name	*Common Name*
Dussia macroprophyllata	sangregao
Sclerolobium costarricense	tostado
Vochysia allenii	botarrama

Source: Poyecto Río San Juan-Amigos de la Tierra(2000).

CCT (2008) mentions that "regarding the flora, the area houses an estimated 354 species of trees, of which 28 are considered threatened and ten are endemic". The previously stated information refers to the Maquenque Refuge, which includes only a section of the Route 1856 study, but covers an extensive area to the South.

A study conducted in the area that represents the forest ecosystems between Border Marker 2 and the mouth of the San Carlos river, on the strip adjoining the San Juan River, (between 2 and 5 km. from the river), adjoining the Infiernito river, for an estimated area of 4,500 hectares, of which some 3,000 are forested, 221 species of trees were identified, and it was estimated that with further study, the number could reach 300 species for this region (CCT, 1996).

This same source found that in this region there are 24 tree species considered threatened, rare species or in danger of extinction and only one species was considered endemic to the country. It is interesting that a large quantity of tree species are threatened or in danger of extinction. These are basically commercial species found in the Costa Rica-Nicaragua border region, thus turning this area into a refuge for endangered species. Following is a list of tree species under different categories of threat.

Chart9: Tree species at risk.

	Species	Common Name	Status	Cause	Altitude
1	Aspidosperma spruceanum	amargo, caretigre	limited		
2	Tabebuia guayacan	corteza, guayacán	threatened	HL	100 - 600
3	Ceiba pentandra	ceiba	threatened		50 - 300
4	Copaifera aromatica	camíbar	threatened	HL	0 - 350
5	Cynometra retusa	guapinol negro	very limited		0 - 150
6	Prioria copaifera	cativo	threatened	HL	0 - 150
7	Sclerolobium costarricense	tostado	endangered	HL	50 - 700
8	Terminalia amazonia	roble coral	threatened		30 - 300
9	Terminalia oblonga	surá, guayabón	threatened		20 - 400
10	Dalbergia melanocardium	bálsamo	threatened		100 - 900
11	Dalbergia glomerata	granadillo	threatened		0 - 500
12	Dipteryx panamensis*	almendro	threatened		
13	Dussia macroprophyllata	sangregao	threatened	HL	0 - 600
14	Hymenolobium mesoamericanum	cola de pavo	endangered	HL	30 - 700
15	Platymiscium pinnatum	cachimbo, cristobal	endangered	HL	0 - 600
16	Humiriastrum diguense	chiricano alegre	threatened	HL	0 - 700
17	Vantanea barbourii	chiricano triste	threatened	HL	0 - 800
18	Povedadaphne quadriporata	ira rosa	rare		
19	Couroupita guianensis	bala de cañon	rare		
20	Lecythis ampla	olla de mono	threatened	HL	50 - 300
21	Ruptiliocarpon caracolito	caracolito	threatened		200 - 650
22	Carapa guianensis	caobilla	decreased		50 - 250
23	Cedrela fissilis*	cedro real	endangered	HL	50 - 500
24	Cedrela odorata	cedro amargo	threatened	HL	0 - 1200
25	Trichilia pittieri		rare		
26	Minquartia guianensis	manú	threatened	HL	0 - 500
27	Podocarpus guatemalensis*	cipresillo, pinillo	endangered	HL	50 - 1500

	Species	Common Name	Status	Cause	Altitude
28	Elaeoluma glabrescens	carey	threatened		50 - 300
29	Sideroxylon capiri	danto amarillo	threatened	HL	0 - 900
30	Christiana africana	piedra	rare		
31	Vochysia allenii	botarrama	rare/ E	HL	
32	Qualea paraensis	areno	threatened	HL	100 - 850

Source: Centro Científico Tropical, 2008, citing: Jiménez, 1993; Jiménez, 1997; Jiménez, com. pers., 2001; Sánchez-Vindas *et al*., 1987; Quesada *et al*., 1997; Holdridge *et al*., 1997; Zamora *et al*., 2000. ***:** according to UICN.Status: E: endemic,Cause HL: hábitat lossCI: intensive hunting or over fishingCO: polution

Despite the high degree of threat that weighs over a large number of lumber species in the Northern Territory, only 5 species were identified whose use has been banned.

Chart10: Species officially under ban.

Species	Common Name
Cedrela fissilis*	Cedro real
Dipteryx panamensis**	Almendro
Hymenolobium mesoamericanum*	Cola de pavo
Podocarpus guatemalensis*	Cipresillo, pinillo
Sclerolobium costarricense*	Tostado

Source: * totally banned due to its critically endangered status, according to decree N° 25700-MINAE, 2008. ** In CITES, Appendix III.

5.1.1.7 Fragility of Terrestrial Ecosystems.

The construction of Route 1856 could attract settlers to the region, generating pressure on the existing services and infrastructure, as well as on the region´s natural protected areas. If this becomes the case, it could imply that natural segments in wild lands could suffer greater vulnerability due to the impact on natural connecting areas, and to contamination due to human activities.

The region where Route 1856 is located contains some characteristics common to frontier rural areas along the Costa Rica-Nicaragua border. It has always been a region of difficult access; in much of the territory access has been through fluvial means. In the case of Costa Rica, where most of the means of collective use- infrastructure and services- have historically been provided by the state, especially after the second half of the 20th Century, border regions have suffered an almost total abandonment, remaining as “no man´s land”, where the benefits of infrastructure and services are relative.

Tropical rainforests are fragile to a large extent due basically to their weak ecological equilibrium. Moreover, many of these forests evolve on poor soils and are susceptible to erosion when altered by human action. Nevertheless, primary forests ecosystems (not altered) are more fragile when considering their susceptibility to sever damage when exploited for commercial purposes, or worse, when cut down completely. Among the primary forest ecosystems present in the area, the primary forest on sloping terrain is the most vulnerable, due to the fact that the

elimination of plant cover leads to very strong erosion. Biodiversity in these ecosystems is negatively affected when important numbers of trees and minor plant species disappear, although the structure, volume of biomass and economic value of lumber species is also affected, as well as species of fauna that are harder to quantify and value.

In the Route 1856 project area, there are few unaltered primary forests, since most of them were subjected to lumber extraction during past decades. The CCT (1996) cites a study conducted during the period mentioned in an area neighbouring the Route area, Crucitas sector and the Infiernito river, where an analysis of 3,000 hectares of forest concluded that only 6% of the forest had not been altered, where no trees had been cut or only 2 trees/hectare had been taken out.

In the same study, forest cover, volume and number of trees and species were analyzed and a comparison was made between altered sites (where lumber extraction had take place) and unaltered sites (primary). The study emphasized that the volume of lumber per hectare was drastically reduced when comparing primary forests in flat terrain (150 m³/ha, with trees larger than 30 cm. DBH) and altered forests (43 m³/ha with trees larger than 30 cm. DBH). Similarly, the number of specimens and species were decimated and the structure of ecological association was extremely altered.

In that regard, an analysis conducted of forests within the study area (between San Carlos and Sarapiquí rivers) shows interesting data on the reduction in the number of tree species, of 27% when comparing primary forests with those that were altered for commercial lumbering purposes in adjoining sites (see Chart 11).

Chart11: Variation in number of species and trees in condition different from forest (in the Biological Border Corridor) in 0,25 ha plots, for trees thicker than 10 cm DBH.

Forest Category	*N° Species*	*N° Trees*
Primary (not intervened)	63	189
	74	198
	70	180
	65	199
	65	160
Average	67	185
Primary intervened	55	121
	53	118
	48	124
	46	119
	47	108
Average	49	118
Secundary (25 years)	45	167
	36	141
Average	40	154

Source: plot data from Proyecto Río San Juan-Amigos de la Tierra (2000).

This shows in some way the susceptibility of these ecosystems, since this degradation of the composition of the ecosystem remains for many decades and in some areas with sparse forest this impoverishment of the forest may become irreversible.

Since this study does not have quantitative information and location for the non-altered primary forest ecosystems, it is assumed that forests characterized as primary are for the most part altered forests. It was possible to observe that between the area of Tiricias and the Infiernito river there is a non-altered primary forest, as well as forests on slopes located between Infiernito and Chorreras. There are some forest remnants that are not altered between the Project and the area of direct influence.

In the case of secondary forest ecosystems, they are considered of medium fragility given that in their characteristic state of immaturity they represent more simple ecosystems and that with elimination of plant cover, the natural processes tend to return to zero. Therefore, when a secondary forest is eliminated, a secondary forest may be generated, whereas, it is difficult to guarantee the restoration of a primary forest. In Chart 10 fragility is qualified for the distinct ecosystems described here.

Even though wetlands generally are fragile ecosystems, especially when there are human activities occurring in their surroundings, such as the process of settlements, roads, or farming activities, it is concluded that for the area and its natural associations, Yolillo patches present the most fragility because they are susceptible to being turned into pasture lands.

Chart12: Fragility of terrestrial ecosystems characterized for this study.

Ecosystem	*Fragility*
Palustrine wetland	Medium
Lacustrine wetland	Medium
Yolillal patch	High
Riverine systems (its protective riverbank)	Medium
Primary forest on sloping terrain	High
Primary forest on flat land	High
Secondary forest on sloping terrain	Medium
Secondary forest on flat land	Medium

Source: CCT, 2013.

5.1.1.7.1 Ecosystems and tree species impacted by human activities in the area of Route 1856

The ecosystems that were identified and determined to have been impacted by the construction of Route 1856 were evaluated through a geographic information system using ecosystem covers (see Chart 13).

Chart13: Area impacted for each ecosystem within the project area.

Natural Ecosystem	*Area (hectares)*	*Proportion (%)*
Primary forest on sloping terrain	59,6	17,0
Secondary forest on sloping terrain	9,4	2,7
Primary forest on flat land	8,8	2,5
Secondary forest on flat land	5,5	1,6
Forest plantation (mature)	1,1	0,3
Yolillo patch	0,7	0,2
Lacustrine wetland	0,1	0,0
Agriculture and livestock uses	265,1	75,7
Total	350,2	100,0

Source: Map of ecosystems, this study.

Relevantly, 75% of the impacted project area was identified as used foragricultureand livestock activities, and was characterized by open pasture lands without trees. This translates into a low percentage of natural areas intervened by the construction of the road and a low general impact.

To complete the information described previously, Annex 9.4 offers a list of threatened species present in the Biological Border Corridor and the Maquenque Wildlife Refuge. Annex 9.5 contains a list of threatened species and species with low numbers, to be used in local reforestation projects. Finally Annex 9.6shows a total list of tree species observed in the area of Las Crucitas, San Carlos.

5.1.1.8 Impacted flora species

It has not been possible to determine the impacted flora species, nor to provide a geo-reference for them, due to the lack of a prior inventory of the existing tree species.

5.1.2 Aquatic Environment (inland water bodies).

The description of the aquatic environment is divided into four main components: aquatic fauna, riverine system description, threatened species and environmental fragility. Each one has specific characteristics that differentiate them in terms of the methods applied and the definition of the direct and indirect influence area.

Regarding the influence areas, for the aquatic component, the direct influence area of the Project (DIA) was defined as all the area contained in the Route, the San Juan River basin and all the bodies of water such as creeks, rivers, channels that traverse Route 1856. The area of indirect influence (IIA) is defined as upstream waters for the bodies of water that are crosscut by the Route, where it is possible that displacement of migratory aquatic species present in the region takes place.

In terms of the description of the aquatic environment, the project area was divided into three sections: 1) From Border Landmark 2 to the mouth of the San Carlos river; 2) From the mouth of

the San Carlos river to the Sarapiquí river confluence with the San Juan River; 3) from the mouth of the Sarapiquí river to the site called Delta Costa Rica.

Border Landmark 2 - Mouth of the San Carlos river

This stretch starts in Border Landmark 2 of Route 1856 and ends at the point where the San Carlos river empties into the San Juan River. In this stretch 28 tributary streams were identified that empty into the San Juan River (see Map 17 and 18). Most of these are steams, channels or small creeks. The larger affluents are the Infiernito river, Caño Jardín and Caño Trinidad.

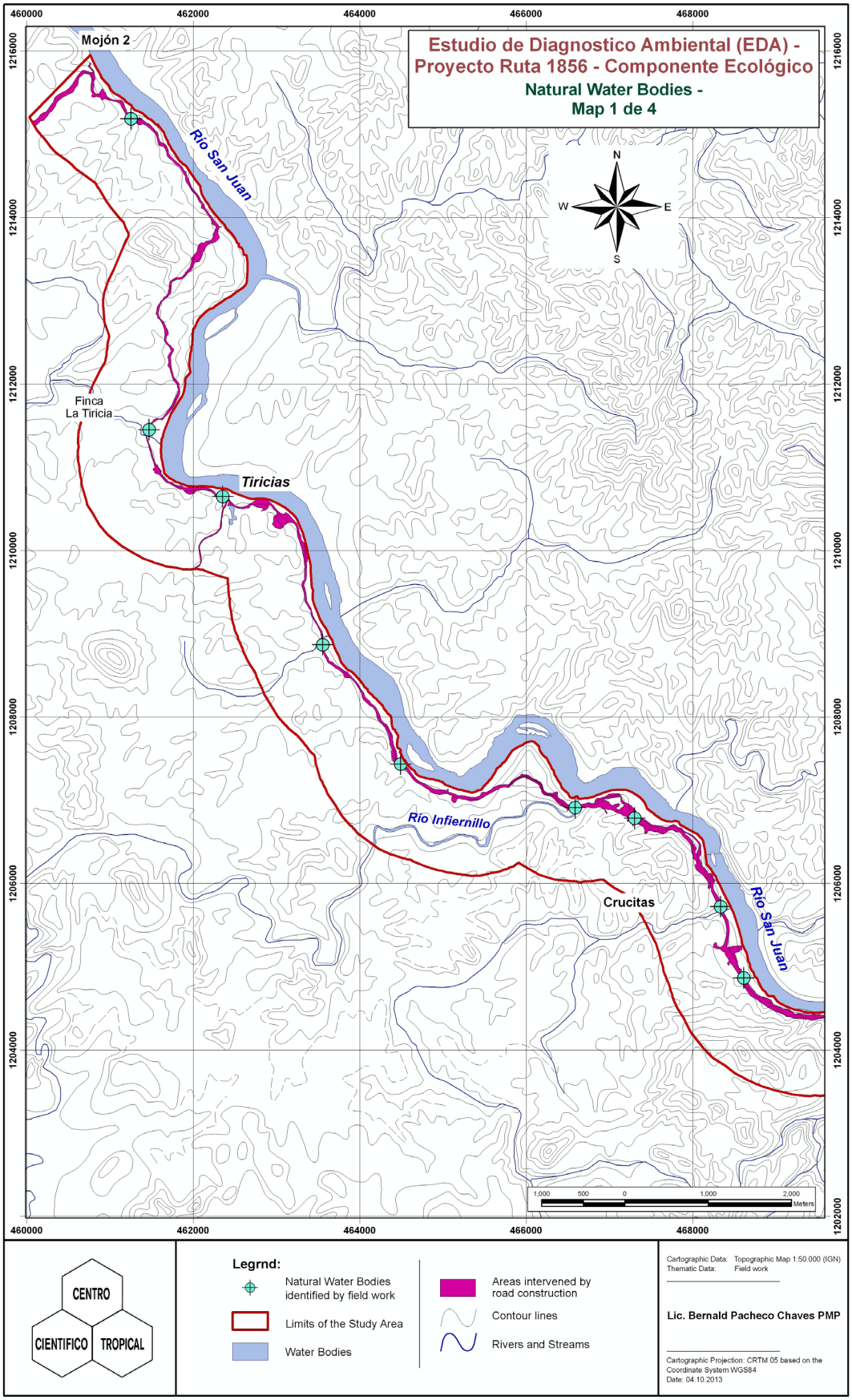
This stretch was identified as the most impacted due to the presence of several unstable slanting retention wall that could create sedimentation, erosion and sediment plumes in the San Juan and its tributaries.

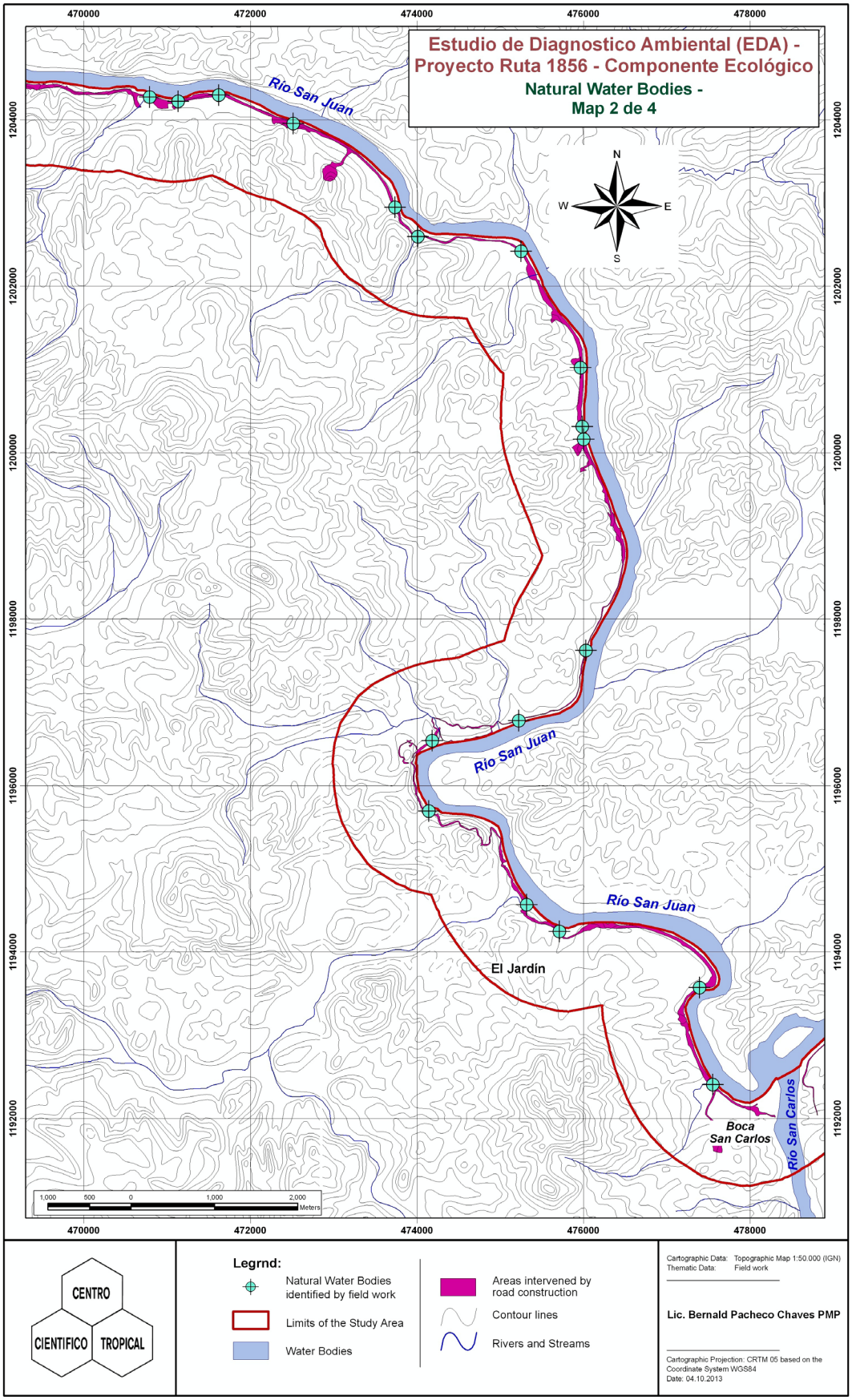
Mouth of the San Carlos - the Mouth of Sarapiquí River

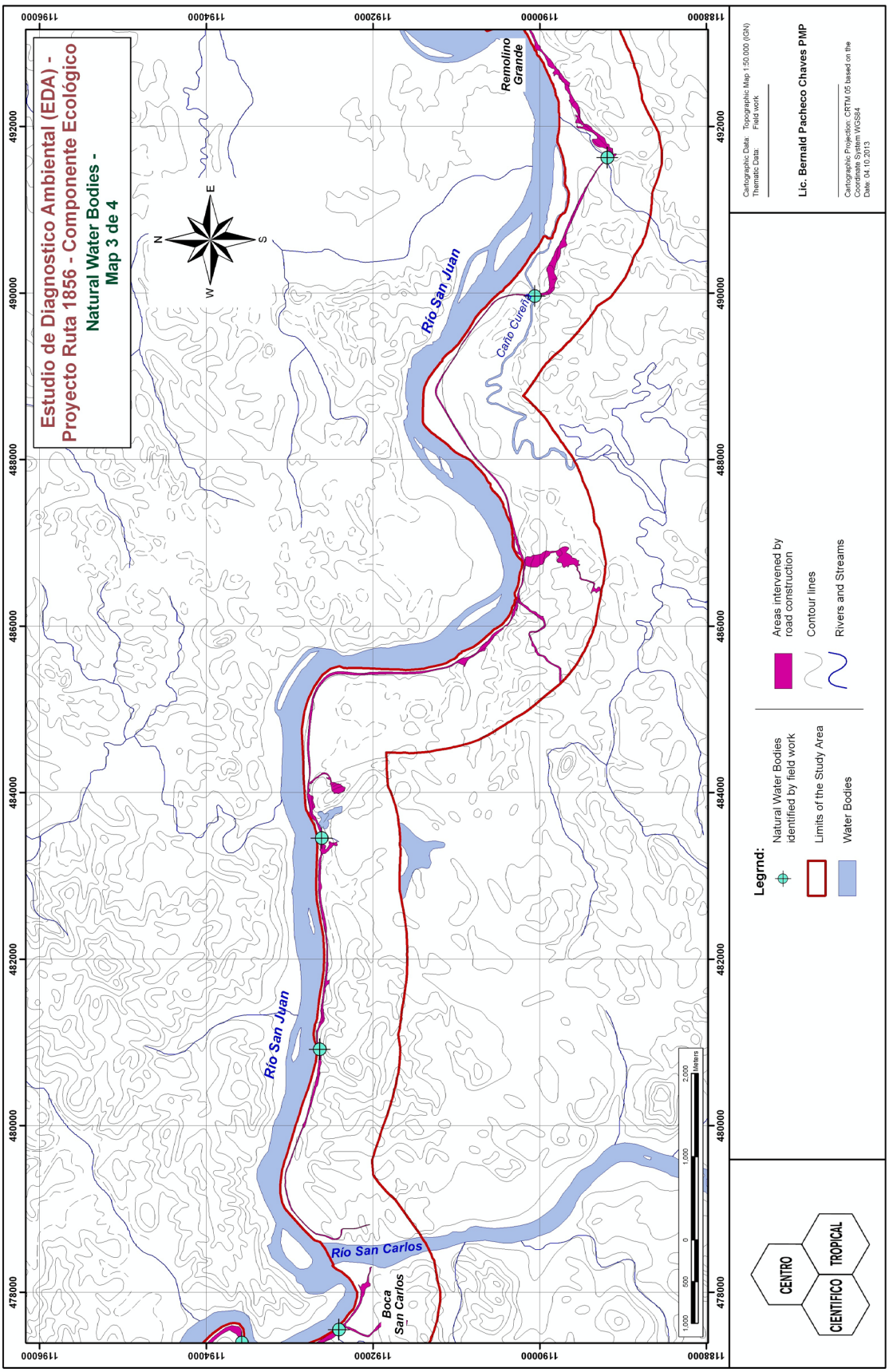
This stretch starts on the left margin of the mouth of the San Carlos river and ends where the Sarapiquí River empties into the San Juan River. In this stretch nine water courses were identified (see Maps 18, 19 and 20), 4 of them creeks without a name, and the remaining five, the largest, are known as Caño Cureña, Cureñita, Tambor, Tamborcito, and Colpachí. Along this stretch are found several sites with steep slopes and eroded retention walls, also red clay soils, which suggested a category of low impact.

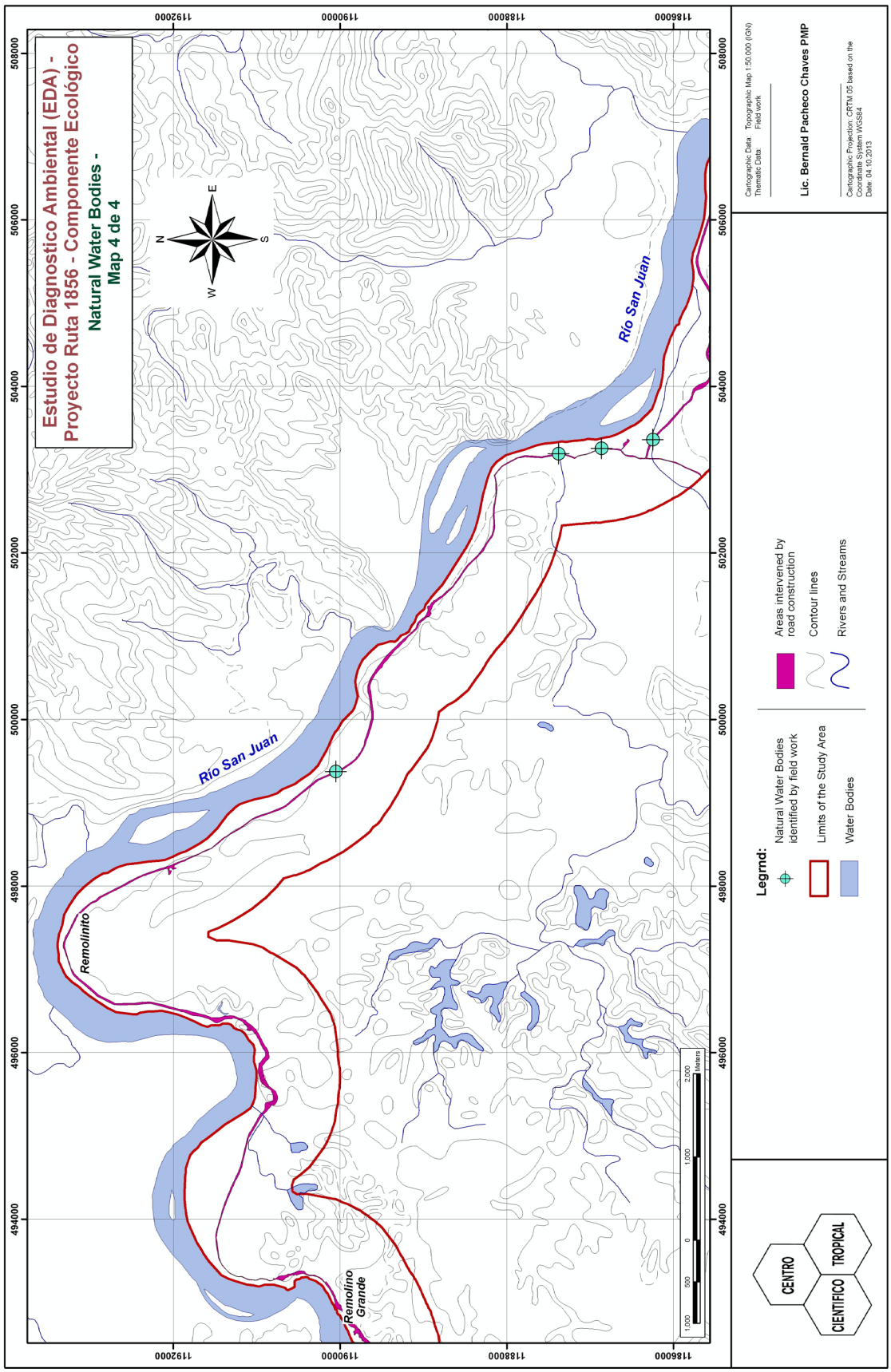
Mouth of the Sarapiquí - Delta Costa Rica

This stretch begins in the Sarapiquí River and ends at the site of Delta Costa Rica on the San Juan River margin. No impacts were registered in this stretch. An extended segment of this stretch is flat and with few unstable retaining walls. Three bodies of water were identified along the stretch (see Map 20), one without name, a second one being a channel known as Caño Tigre and the third one the Maria river.


Estudio de Diagnostico Ambiental (EDA) -
Proyecto Ruta 1856 - Componente Ecológico
Natural Water Bodies -
Map 1 de 4
Mojón 2
Río San Juan
Finca
La Tiricia
Tiricias
Río Infiernillo
Crucitas
Río San Juan
N
W
E
S
460000
462000
464000
466000
468000
1216000
1214000
1212000
1210000
1208000
1206000
1204000
1202000
1,000 500 0 1,000 2,000
Meters
CENTRO
CIENTIFICO
TROPICAL
Legrnd:
Natural Water Bodies identified by field work
Limits of the Study Area
Water Bodies
Areas intervened by road construction
Contour lines
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Field work
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Estudio de Diagnostico Ambiental (EDA) -
Proyecto Ruta 1856 - Componente Ecológico
Natural Water Bodies -
Map 2 de 4
Rio San Juan
Río San Juan
Río San Juan
El Jardín
Boca
San Carlos
Río San Carlos
N
W
E
S
470000
472000
474000
476000
478000
1204000
1202000
1200000
1198000
1196000
1194000
1192000
1,000 500 0 1,000 2,000
Meters
CENTRO
CIENTIFICO
TROPICAL
Legrnd:
Natural Water Bodies identified by field work
Limits of the Study Area
Water Bodies
Areas intervened by road construction
Contour lines
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Field work
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Estudio de Diagnostico Ambiental (EDA) - Proyecto Ruta 1856 - Componente Ecológico
Natural Water Bodies - Map 3 de 4
Río San Juan
Río San Carlos
Boca San Carlos
Remolino Grande
Caño Cureña
Río San Juan
Legrnd:
Natural Water Bodies identified by field work
Limits of the Study Area
Water Bodies
Areas intervened by road construction
Contour lines
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Field work
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO
TROPICAL
CIENTIFICO


Estudio de Diagnostico Ambiental (EDA) - Proyecto Ruta 1856 - Componente Ecológico
Natural Water Bodies - Map 4 de 4
Río San Juan
Río San Juan
Remolinito
Remolino Grande
Legrnd:
Natural Water Bodies identified by field work
Limits of the Study Area
Water Bodies
Areas intervened by road construction
Contour lines
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Field work
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO
TROPICAL
CIENTIFICO

5.1.2.1 Aquatic Fauna

a. Vertebrates

Chart 14 presents a list of all species of fish (74), mammals (4), amphibians (7), reptiles (10) and birds (42) that have been reported in the available literature about the study area. The chart includes the family, common name, scientific name and the distribution of the species.

b. Macroinvertebrates

Aquatic macroinvertebrates are defined as those that can be observed without instruments and whose life cycle includes partial involvement with an aquatic environment. The macroinvertebrate aquatic community is composed of diverse invertebrate groups such as worms, leeches, molluscs, crustaceans, acaroids and mainly juvenile states of several orders of insects. In Chart 15 presents a list of aquatic macro-invertebrates taxa that have been collect in previous studies close the project area. It reports 93 genera, 73 families, 21 orders, 9 claes and 5 phyla.

c. Phytoplancton

Phytoplancton is formed by live organisms of vegetal origin (algae) that live in a body of water, floating on a water column or remained adhered to diverse substrate such as vascular plants, on other algae and on animals. Algae are autotrophic organisms capable of performing photosynthesis. Their importance is fundamental given the fact that they are the most important primary producers in aquatic ecosystems.

Chart 16 presents a list of some genera and species that have been reported in previous studies conducted in eight tributary rivers of the San Juan River which includes the San Carlos and Sarapiquí rivers (upstream and in the mouth). The study reported 65 genera and 54 species belonging to the following groups: Chlorophyta (28), Bacillariophyta (21) Cyanophyta (9), Euglenophyta (3), Dinophyta (2), and Cryptophyta (2).

Chart14: List of aquatic fauna recorded for the project area and surroundings.

Family	*Species*	*Common Name*	*Distribution in the area*
Fishes			
Anguillidae	*Anguilla rostrata*	Anguila	Ríos de la zona norte
Atherinidae	*Atherinella chagresi* **	Sardina	Vertiente atlántica
	Atherinella hubbsi	Sardina	Tributarios del sistema fluvial del río San Juan, lago Nicaragua
	Atherinella milleri	Sardina	Cuenca del río San Juan
	Atherinella sardina	Sardina	Lago Nicaragua, río San Juan *
Carangidae	*Caranx latus*	Jurel	Vertiente atlántica, Tortuguero
	Oligoplites palometa	Pez cuero	Río San Juan, río Sarapiquí
Carcharhinidae	*Carcharhinus leucas*	Madrecazón, Tiburón Toro	Lago de Nicaragua, río San Juan, río San Carlos, río Puerto Viejo y río Sarapiquí

Family	Species	Common Name	Distribution in the area
Centropomidae	*Centropomus parallelus*	Calva	Barra de Colorado, San Juan, Río Infiernillo, lago de Nicaragua
	Centropomus pectinatus	Gualaje Atlántico	Vertiente atlántica
	Centropomus undecimalis	Robalo	Vertiente atlántica
Characidae	*Astyanax aeneus*	Sardina, Plateada, Colirroja, Golosa	Vertiente Atlántica (ubicua), lago de Nicaragua
	Astyanax nasutus	Sardina lagunera	Lago de Nicaragua, río San Juan y sus tributarios, río Colorado, Tortuguero
	Bramocharax bransfordii	Sardina picuda	Vertiente Atlántica, lago de Nicaragua, río San Juan
Characidae	*Brycon guatemalensis*	Machaca, Sabalete	Vertiente Atlántica, río San Carlos, río Sarapiquí
	Bryconamericus scleroparius	Sardina de quebrada	Vertiente Atlántica, río San Juan
	Carlana eigenmanni	Sardinita	Lago de Nicaragua, sistema fluvial del río San Juan
	Hyphessobrycon tortuguerae	Sardinita	Vertiente Atlántica, tributarios del río San Juan, río Tortuguero
	Roeboides bouchellei	Sardinita, Alma seca, Changuito	Vertiente Atlántica, río Sarapiquí
Cichlidae	*Amphilophus citrinellus*	Mojarra	Lago de Nicaragua, río San Juan hasta río Matina.
	Amphilophus labiatus	Mojarra	Lago de Nicaragua, río San Juan *
	Asthatheros alfari	Mojarra	Zona norte, vertiente atlántica, Río Puerto Viejo
	Asthatheros longimanus	Cholesca, Carate, Pecho rojo	Río San juan y tributarios, lago de Nicaragua
	Asthatheros rostratus	Masamiche	Lago de Nicaragua y sistema fluvial del río San Juan hasta el río Matina
	Archocentrus centrarchus	Mojarra	Vertiente Atlántica, lago de Nicaragua, río San Juan y sus tributarios
	Archocentrus nigrofasciatus	Congo, Carate, Burra	Zona norte y atlántica
	Archocentrus septemfasciatus	Mojarra	Vertiente atlántica entre el sistema del río San Juan y cuenca del río Banano

Family	Species	Common Name	Distribution in the area
	Herotilapia multispinosa	Cholesca, Mojarrita	Lago de Nicaragua, zona norte y vertiente atlántica
	Hypsophrys nicaraguensis	Moga amarilla	Lago de Nicaragua, sistema fluvial del río San Juan y tributarios hasta la cuenca del río Matina
Cichlidae	*Neetroplus nematopus*	Moga	Lago de Nicaragua y los tributarios del río San Juan.
	Parachromis dovii	Guapote, Lagunero	Vertiente atlántica, zona norte río Puerto Viejo de Sarapiquí y lago de Nicaragua
	Parachromis friedrichsthalii	Guapote	Río San Juan *
	Parachromis loisellei	Guapotito, Guapote amarillo	Zona norte, Vertiente atlántica
	Parachromis managuensis	Guapote tigre, Guapote barcino	Lago de Nicaragua, vertiente atlántica y río San Carlos
	Theraps underwoodi	Vieja, moga verde, Tuba	Vertiente atlántica, zona norte, río Sarapiquí
	Vieja maculicauda	Pis pis, Palometa, Vieja	Vertiente atlántica, zona norte
Clupeidae	*Dorosoma chavesi*	Sabalete	Lago de Nicaragua, río San Juan, río Colorado, boca del río Sarapiquí, lago Caño Negro y Tortuguero,
Eleotridae	*Dormitator maculatus*	Guarasapa, Pipón	Vertiente atlántica, zona norte
	Eleotris amblyopsis	Pez perro, Guabina, Lucia	Vertiente atlántica, zona norte
	Eleotris pisonis	Pez perro	Vertiente atlántica, zona norte, río San Juan
	Gobiomorus dormitor	Guavina, Bocón	Vertiente atlántica, zona norte, río Sarapiquí
	Hemieleotris latifasciatus	Guavinita	Río San Juan y zona norte
Gerreidae	*Eugerres plumieri*	Mojarra prieta, mojarra fina	Lago de Nicaragua, río San Juan
Gobiesocidae	*Gobiesox nudus*	Chupapiedra	Río Sarapiquí
Gobiidae	*Awaous banana*	Lamearena	Vertiente atlántica, zona norte, río Sarapiquí, río San Carlos
	Sycydium altum	Chupapiedra, Tití	Vertiente atlántica, zona norte

Family	Species	Common Name	Distribution in the area
Gymnotidae	*Gymnotus cylindricus*	Barbudo	Río San Juan *
	Gymnotus maculosus	Madre de barbudo	Tributarios del río San Juan, ríos San Carlos y Sarapiquí
Haemulidae	*Pomadasys crocro*	Roncador	Río Sarapiquí, río San Carlos
Lepisosteidae	*Atractosteus tropicus*	Gaspar, Gar	Lago de Nicaragua, río San Juan y tributarios, San Carlos, Tortuguero y lago Caño Negro
Megalopidae	*Megalops atlanticus*	Sábalo Real	Lago de Nicaragua y los tributarios del río San Juan en la zona norte, río Puerto Viejo, río Sarapiquí, río San Carlos y río Peñas Blancas.
Mugilidae	*Agonostomus monticola*	Tepemachín	Zona norte, río San Carlos
	Joturus pichardi	Bobo	Vertiente Atlántica, río San Carlos, río Sarapiquí
Pimelodidae	*Rhamdia guatemalensis*	Barbudo	Vertiente Atlántica
	Rhamdia nicaraguensis	Barbudo	Vertiente Atlántica
	Rhamdia rogersi	Barbudo	Vertiente Atlántica, tributarios del río San Juan
Poeciliidae	*Alfaro cultratus*	Olomina	Vertiente atlántica
	Belonesox belizanus	Pepesca gaspar	Vertiente Atlántica, lago de Nicaragua, río Tortuguero
	Brachyrhaphis holdridgei	Olomina	Vertiente Atlántica, río San Carlos
	Brachyrhaphis parismina	Olomina	Vertiente Atlántica, río San Juan
	Gambusia nicaraguensis	Olomina	Vertiente atlántica
	Neoheterandria umbratilis	Olomina	Lago de Nicaragua, vertiente atlántica
Poeciliidae	*Phallichthys amates*	Olomina	Zona norte y atlántica
	Phallichthys tico	Olomina	Lago de Nicaragua y en tributarios del río San Juan.
	Poecilia gillii	Olomina	Vertiente atlántica
	Poecilia mexicana	Olomina	Vertiente atlántica
	Poecilia sphenops	Olomina	Río San Juan *
	Priapichthys annectens **Ω**	Olomina	Vertiente atlántica, tributarios del lago Nicaragua
Pristidae	*Pristis pectinata*	Pez sierra, Peje peine	Río San Juan, lago de Nicaragua *
	Pristis perotteti	Pez sierra, Peje peine	Río San Juan, lago de Nicaragua *
	Pristis pristis	Pez sierra, Pejesierra	Afluentes del río San Juan en la zona norte

Family	Species	Common Name	Distribution in the area
Rivulidae	*Rivulus isthmensis*	Olomina	Río Sarapiquí, lago de Nicaragua, vertiente atlántica
Synbranchidae	*Synbranchus marmoratus*	Anguila de pantano, anevila	Zona norte
Syngnathidae	*Pseudophallus mindii*	Pez pipa	Zona norte y atlántica
Mammals			
Mustelidae	*Lontra longicaudis*	Nutria, Perro de agua	Vertiente del caribe, río Sarapiquí
Trichechidae	*Trichechus manatus*	Manatí, Vaca marina	Vertiente del caribe, río San Juan
Tapiridae	*Tapirus bairdii*	Tapir, Danta	Vertiente del caribe
Didelphidae	*Chironectes minimus*	Zorro de agua	Vertiente del caribe
Amphibians			
Bufonidae	*Bufo haematiticus*		Vertiente atlántica
	Bufo valliceps		Vertiente atlántica, parte alta de la cuenca del río San Juan
Leptodactylidae	*Leptodactylus melanonotus*		Vertiente atlántica
	Leptodactylus labialis		Vertiente atlántica, parte alta del río San Juan
	Eleutherodactylus bransfordii		Vertiente atlántica, río San Juan
Ranidae	*Rana taylori*		Vertiente atlántica
	Rana vaillanti		Vertiente atlántica
Reptiles			
Iguanidae	*Iguana iguana*	Iguana, Iguana verde	Vertiente atlántica
Colubridae	*Thamnophis marcianus*		Lago de Nicaragua, cuenca del río San Juan
	Thamnophis proximus		Cuenca del río San Juan y río Colorado
Dipsadidae	*Tretanorhinus nigroluteus****	Culebra de manglar quilada	Vertiente atlántica
Kinosternidae	*Kinosternon leucostomum*	Tortuga amarilla	Vertiente atlántica
Chelydridae	*Chelydra serpentina*	Tortuga lagarto	Vertiente atlántica
Geoemydidae	*Rhinoclemmys funerea*	Tortuga negra del río	Vertiente atlántica

Family	Species	Common Name	Distribution in the area
Emydidae	*Chrysemys ornata*	Tortuga resbaladora	Vertiente atlántica, lago de Nicaragua, cuenca del río San Juan
Crocodylidae	*Caiman crocodilus*	Caiman, Lagarto	Vertiente atlántica, río San Juan
	Crocodylus acutus	Cocodrilo, Lagarto negro	Vertiente atlántica, río San Juan
Birds			
Alcedinidae	*Ceryle alcyon*	Martín pescador norteño	Vertiente del Caribe
	Ceryle torquata	Martín pescador collarejo	Vertiente del caribe
	Chloroceryle aenea	Martín pescador enano	Vertiente del caribe
	Chloroceryle amazona	Martín pescador amazónico	Vertiente del caribe
	Chloroceryle inda	Martín pescador vientrirrufo	Vertiente del caribe
Anatidae	*Anas acuta*	Pato rabudo	Vertiente del caribe
	Anas clypeata	Pato cuchara	Vertiente del caribe
	Anas crecca	Cerceta aliverde, Zarceta	Vertiente del caribe
	Anas cyanoptera	Cerceta castaña	Vertiente del caribe
	Anas discors	Cerceta aliazul, Zarceta	Vertiente del caribe
	Aythya affinis	Porrón menor	Vertiente del caribe
	Aythya callaris	Porrón collarejo	Vertiente del caribe
	Cairina moschata	Pato real, Pato perulero	Vertiente del caribe
	Dendrocygna autumnalis	Pijije común, Piche	Vertiente del caribe
	Dendrocygna viduata	Pijije cariblanco, Piche careto	Vertiente del caribe

Family	Species	Common Name	Distribution in the area
	Oxyura dominica	Pato enmascarado	Vertiente del caribe
Anhingidae	*Anhinga anhinga*	Pato aguja, aninga	Vertiente del caribe
Ardeidae	*Agamia agami*	Garza pechicastaña	Vertiente del caribe
	Ardea herodias	Garzón azulado	Vertiente del caribe
Ardeidae	*Botaurus pinnatus*	Avetoro, Puncus, Mirasol	Vertiente del caribe
	Butorides striatus	Garcilla verde, Chocuaco, Martín peña	Vertiente del caribe
	Casmerodius albus	Garceta grande	Vertiente del caribe
	Egretta caerulea	Garceta azul	Vertiente del caribe
	Egretta thula	Garceta nivosa	Vertiente del caribe
	Egretta tricolor	Garceta tricolor	Vertiente del caribe
	Tigrisoma fasciatum	Garza tigre, Martín peña, Pajaro Vaco	Vertiente del caribe
	Tigrisoma lineatum	Garza tigre, Martín peña, Pajaro Vaco	Vertiente del caribe
	Tigrisoma mexicanum	Garza tigre, Martín peña, Pajaro Vaco	Vertiente del caribe
Ciconiidae	*Jabiru mycteria*	Jabiru	Vertiente del caribe
	Mycteria americana	Cigüeñon, Garzón, Guairón	Vertiente del caribe
Heliornithidae	*Heliornis fulica*	Perrito de agua, Toboba	Vertiente del caribe, Corredor Biológico San Juan - La Selva
Phalacrocoracidae	*Phalacrocorax olivaceus*	Cormorán, Pato chancho, Pato de agua	Vertiente del caribe
Podicipedidae	*Podilymbus podiceps*	Zambullidor Piquipinto, Pato de agua	Vertiente del caribe

Family	Species	Common Name	Distribution in the area
	Tachybaptus dominicus	Zambullidor Enano, Patillo, Pato de agua	Vertiente del caribe
Rallidae	*Amaurolimnas concolor*	Rascón café	Vertiente del caribe
	Aramides cajanea	Rascón cuelligrís	Vertiente del caribe
Scolopacidae	*Limnodromus scolopaceus*	Agujeta silbona, Piquilarga	Vertiente del caribe
	Tringa solitaria	Andarríos solitario	Vertiente del caribe
Threskiornithidae	*Eudocimus albus*	Ibis blanco, Coco	Vertiente del caribe
	Mesembrinibis cayennensis	Ibis verde, Coco negro	Vertiente del caribe
	Plegadis chií	Ibis cariblanco	Vertiente del caribe
	Plegadis falcinellus	Ibis morito, Coco negro	Vertiente del caribe

Source: (Fishes: Bussing, 1976 *; Bussing, 1998; Rojas, 2002 **; Espinoza, 2008; INBIO, 2013; Mammals: Carillo *et al.*, 2002; Amphibians and Reptiles: Savage, 2002; Birds: Style & Skuth 1989).

Chart15: List of aquatic macroinvertebrate taxa for the project area and surroundings.

Phylum – Class	Order	Family	Taxon ***
Arthropoda			
Arachnida	Trombidiformes	Fam. indet.	
Insecta	Coleoptera	Curculionidae	
		Dryopidae ***	*Dryops*
			Elmoparnus
		Dytiscidae ***	
		Elmidae	*Cylloepus*
			Heterelmis
			Macrelmis
			Microcylloepus
			Neoelmis
			Phanocerus
		Gyrinidae	*Gyrinus*
		Hydrophilidae ***	*Tropisternus*
		Hydroscaphidae	

Phylum – Class	Order	Family	Taxon ***
		Psephenidae	*Psephenus*
		Ptilodactylidae	*Anchytarsus*
		Scirtidae ***	
		Staphilinidae ***	
	Diptera	Blephaceridae	*Paltostoma*
		Ceratopogonidae	
		Chironomidae	*Chironomus*
			Xestochironomus
			Chironominii
			Orthocladinae
			Tanypodinae
		Culicidae ***	*Anopheles*
			Culex
	Diptera	Empididae	
		Muscidae	
		Psychodidae ***	*Maruina*
		Simulidae *	*Simulium*
		Tabanidae ***	
		Tipulidae	*Hexatoma*
			Limonia
	Ephemeroptera	Baetidae	*Americabaetis*
			Baetodes
			Callibaetis
			Camelobaetidius
			Cloeodes
		Caenidae	*Caenis*
		Heptagenidae ***	*Stenonema*
		Leptohyphidae	*Asioplax*
			Epiphrades
			Leptohyphes
			Tricorythodes
			Vacuperinus
		Leptophlebiidae	*Farrodes*

Phylum – Class	Order	Family	Taxon ***
			Terpides
			Thraulodes
			Traverella
			Ulmeritoides
		Polymitarcyidae	
	Hemiptera	Gerridae	
		Veliidae	*Rhagovelia*
		Belostomatidae *	
		Hebridae	*Hebrus*
		Naucoridae ***	*Cryphocricos*
			Limnocoris
	Hemiptera	Mesoveliidae ***	*Mesovelia*
		Nepidae ***	*Ranatra*
		Notonectidae ***	*Buenoa ?*
	Odonata	Aeshnidae *	
		Calopterygidae	*Hetaerina*
		Coenagrionidae	*Acanthagrion*
			Argia
			Leptobasis
			Telebasis
		Megapodagrionidae ***	*Heteragrion*
		Platystictidae ***	*Palaemnema*
		Protoneuridae ***	
		Gomphidae	*Agriogomphus*
			Desmogomphus
			Erpetogomphus
			Phyllocycla
			Phyllogomphoides
		Libellulidae	*Brachymesia*
			Brechmorhoga
			Dythemis
			Erythemis
			Erythrodiplax

Phylum – Class	Order	Family	Taxon ***
			Macrothemis
			Miathyria
			Nephepeltia
			Pantala
			Perithemis
			Tramea
		Protoneuridae *	
	Trichoptera	Calamoceratidae	*Phylloicus*
		Helicopsychidae ***	*Helicopsyche*
		Glossosomatidae ***	*Protoptila*
			Culoptila
		Hydropsychidae	*Leptonema*
			Macronema
			Macrostemum
			Smicridea
		Hydroptilidae	*Alisotrichia*
			Zumatrichia ?
		Leptoceridae	*Nectopsyche*
			Oecetis
			Triplectides
		Limnephilidae	
		Odontoceridae	
		Philopotamidae	*Chimarra*
		Polycentropodidae	*Polycentropus*
	Megaloptera	Corydalidae ***	*Corydalus*
			Chloronia
	Plecoptera	Perlidae	*Anacroneuria*
	Lepidoptera	Crambidae *	*Petrophila*
	Blattodea	Blaberidae ***	*Epilampra?*
Malacostraca	Decapoda	Palaemonidae	*Macrobrachium***
			Macrobrachium carcinus **
			Macrobrachium acanthurus **
			Macrobrachium olfersi **

Phylum – Class	Order	Family	Taxon ***
		Atyidae **	*Potimirin*
		Pseudothelphusidae	
	Isopoda		
Ostracoda	Podocopida	Candonidae	
	Ord. indet.	Fam. indet.	
Mollusca			
Bivalvia	Unionoida	Unionidae	
Gastropoda	Basommatophora	Ancylidae ***	
		Lymnaeidae *	
		Physidae	
		Planorbidae ***	
	Mesogastropoda	Cyclophoridae	
	Neotaenioglossa	Hydrobiidae	
		Naticidae	
Monoplacophora	Ord. indet.	Fam. indet.	
Nematoda			
Clase indet.	Ord. indet.	Fam. indet.	
Annelida			
Clitellata	Rhynchobdellida	Glossiphoniidae	
	Haplotaxida	Naididae *	
		Fam. indet.	
Platyhelminthes			
Turbellaria	Tricladida	Planariidae ***	

Source: Fenoglio *et al*., 2002 *; Lara, 2006 **; Springer, 2008 ***; Salvatierra *et al.,* 2013.

Chart16: Listof phytoplancton species recorded for the San Juan tributaries.

Division / Species	Division / Species	Division / Species
Cyanophyceae	*Navicula cuspidata*	*Dictyosphaerium sp.*
Anabaena sp.	*Navicula sp.*	*Gonium sp.*
Anabaenopsis raciborskii	*Nitzschia acicularis*	*Kichneriella obesa*
Anabaenopsis sp.	*Nitzschia palea*	*Kirchneriella lunaris*
Chroococcus giganteus	*Nitzschia sigmoidea*	*Kirchneriella sp.*
Chroococcus limneticus	*Nitzschia sp.*	*Micrasterias foliacea*

Division / Species	Division / Species	Division / Species
Chroococcus sp.	*Pinnularia dactylus*	*Micrasterias furcata*
Chroococcus turgidus	*Pinnularia mayor*	*Micrasterias radiosa*
Gomphosphaeria sp.	*Pinnularia nobilis*	*Monoraphidium skujae*
Lyngbya contorta	*Pinnularia sp.*	*Monoraphidium sp.*
Lyngbya limnetica	*Pleurosigma sp.*	*Oocystis lacustris*
Merismopedia elegans	*Rhizosolenia sp.*	*Oocystis sp.*
Merismopedia sp.	*Rhopalodia sp.*	*Pandorina sp.*
Microcystis aeruginosa	*Stauroneis acuta*	*Pediastrum duplex*
Microcystis sp.	*Surirella biseriata*	*Pediastrum simplex*
Oscillatoria sp.	*Surirella linearis*	*Pediastrum tetras*
Spirulina sp.	*Surirella sp.*	*Pseudostaurastrum lobulatum*
	Surirella turgida	*Scenedesmus acuminatus*
Bacillariophyta	*Synedra rupens*	*Scenedesmus quadricauda*
Achnanthes sp.	*Tabellaria sp.*	*Scenedesmus sp.*
Amphipleura lindheimeri	*Terpsinoe musica*	*Shroederia sp.*
Asterionella sp.		*Spirogyra sp.*
Aulacoseira ambigua	Chlorophyta	*Staurastrum sp.*
Aulacoseira distans	*Actinastrum sp.*	*Tetraedron regulare*
Aulacoseira granulata	*Ankistrodesmus bernardii*	*Tetraedron sp.*
Aulacoseira islandica	*Ankistrodesmus sp.*	*Tetrastrum sp.*
Aulacoseira subarctica	*Botryococcus braunii*	*Treubaria sp.*
Cyclotella pseudostelligera	*Chlamydomonas sp.*	
Cyclotella sp.	*Chlorella sp.*	Euglenophyta
Bacillariophyta	Chlorophyta	Euglenophyta
Denticula sp.	*Chlorolobion braunii*	*Euglena acus*
Eunotia asterionelloides	*Chlorolobion sp.*	*Phacus sp.*
Eunotia sp.	*Chodatella sp.*	*Trachelomonas sp.*
Fragilaria crotonensis	*Closterium sp.*	
Fragilaria pinnata	*Coelastrum sp.*	Cryptophyta
Fragilaria sp.	*Cosmarium connatum*	*Cryptomonas sp.*
Fragilaria ulna	*Cosmarium margaritiferum*	*Rhodomonas sp.*
Gomphonema sp.	*Cosmarium sp.*	
Melosira italica	*Crucigenia sp.*	Dinophyta

Division / Species	Division / Species	Division / Species
Melosira sp.	*Desmidium aptogonum*	*Gymnodinium sp.*
Navicula cryptocephala	*Desmidium sp.*	*Peridinium sp.*

Source: Chow, (s.f.).

5.1.2.2 Characterization of the Riparian System.

The fluvial and riparian systems are intimately and directly related to the terrestrial environment (Peterjohn and Correl, 1984; Talley et al. 2006). The riverbank area contains the interphase between liquid and solid, a characteristic of the most productive ecosystems (Doppelt *et al.* 1993; Pringle 2006). The riverbank vegetation is an important component of a watershed because it provides a significant percentage of the nutrients that reach the river´s alimentary network and the load of epirreica water (epi-continental) and hiporreica (underground coastal current).

Even under extreme conditions and extensive periods of dry climate these corridors always maintain a prosperous vegetation. They are very valuable systems for the surrounding environment (Laurance 2004; Mata and Quevedo 2005). It is of basic importance to regulate strictly any variation that must be effected on the normal flux of the channels, streams and creeks in the study area (Chassot *et al.* 2006, 2010).

Riparian ecosystems of the study area are characterized by a marked presence of species such as the “sotacaballo” (*Zygdia confuse*), “gavilan” (*Pentaclethra macroloba*), “poponjoche” (*Pachira acuatica*) and “caobilla” (*Carapa guanensis*). Also common are pioneering species such as the “guarumo” (*Cecropia spp*) and the “balsa” (*Ochroma pyramidale*). In the ecosystems or associations of “Yolillo” the dominant tree is the Yolillo palm (*Raphia taedigera*) (CCT, 2008).

The riparian forest is characteristic of the region, with very large trees that border the channels leading to the lagoons, with a very attractive species called “cativo” (*Prioria copaifera*) which forms very pure hoops above all at the entrance to Caño Tambor. These are accompanied by “caobilla” and ficus. The undergrowth here is constituted by masses of palm trees of the genus *Geonoma* as well as *Heliconia*. The canopy has a great quantity of bromeliads and orchids.

5.1.2.3 Indicator Species.

An indicator species is an organism that has been selected for its sensibility or tolerance to diverse types of contamination and alteration or to its effects within the organism´s habitat. The response of biological indicators is founded on their capacity to respond in an integrated manner to the effects of eventual or permanent perturbances in the environment where they grow and develop.

In aquatic environments generally there is no assessment of the condition of a species, instead it is performed on groups of organisms or the structure of the community; outstanding among these are the aquatic macro-invertebrates (Res and Jackson 1963; Segnini 2003). The structure of a community depends on the composition and abundance of the species that form it. In general terms it is safe to say that the structure of the aquatic community reflects the historical factors and environmental conditions that prevail there (Resh and Jackson, 1993).

Aquatic macroinvertebrates are considered to be appropriate bio-indicators of the quality of water, followed by algae, fish and macrophytes, due to the fact that they are sensitive to the contamination and respond rapidly to changes in structure of the community; they are easily

identified and sampled; they are abundant and have a cosmopolitan distribution; they are relatively sedentary and thus are representative of the area where they are collected, and can be used to estimate biotic indexes (Roldan 2003; Segnini 2003).

Biotic indexes are fast and simple methods that are utilized habitually in biological monitoring to evaluate the quality of water using aquatic macro-invertebrates as bio-indicators (Roldan 2003). Used in Costa Rica, the BMWP-CR (Biological Monitoring Working Party modified for Costa Rica) assigns points to the families according to the tolerance of different groups to contamination. The total value of the index is obtained by adding the points for each family, independently of abundance or diversity (MINAE-S 2007).

The collection of aquatic macro-invertebrates to determine the structure of the aquatic community and calculate the BMWP-CR index is done through a standardized sampling methodology of multi-habitat macro-invertebrates with the use of a “D” net and a net light of 0,5 mm. (Photograph 1).

At each sampling site the types of micro-habitats and substrata are identified to collect organisms and the collection is done over a total effort of 1 hour. All collected material is identified and stored in plastic containers and preserved in 70% alcohol.

The collected organisms are identified with the use of taxonomic keys (Merritt *et al*., 2008; Springer et al. 2010; Pacheco Chaves 2010; Oceguera-Figueroa and Pacheco Chaves 2012) up to the maximum taxonomic level possible (mostly up to the level of genera). The material identified is deposited in the aquatic insect collection of the Zoology Museum of the University of Costa Rica.

Photograph1: Collection of aquatic macroinvertebrates acuáticos with “D” net. Route 1856, 2013.

5.1.2.3.1 Description of study sites

In order to assess the effects of the construction of Route 1956 on the aquatic ecosystems that cut across the road and empty into San Juan River, 10 lotic bodies of water (creeks, channels and rivers) were selected, the structure of the communities was characterized and the quality of

water was evaluated calculating the MWP-CR index (MINAE-S, 2007) making use of the aquatic macro-invertebrates group as indicator species.

In each of the bodies of water two sampling points were located, one upstream (no direct influence) where the road crosses the body of water, and another one downstream (direct influence) for a total of 20 sampling points.

Data on the sampling locations is identified as geographic coordinates (decimal degrees, Datum WCS 84). The type of water course of all rivers identified and sampled along the Route project is low- taking into account their location in the watershed- and all rivers end in the San Juan River. Chart 17 describes the sites and points sampled for the study.

5.1.2.3.2 Structure of aquatic macroinvertebrates communities

The Project area is represented by 73 genera, 58 families and 21 orders (see Annex 9.4) of a total of 957 collected specimens, whose distribution and abundance is determined by the kind of habitat in the region. The most abundant orders and families were Ephemeroptera (Baetidae, Lepthophlebiidae and Leptohyphidae), Hemiptera (Notonectidae) and Diptera (Chironomidae). The families with the greatest diversity of genera were Baetidae (Ephemeroptera), Gerridae (Hemiptera) and Elmidae (Coleoptera) with 5 genera each (see Annex 9.4)

Some of the macro-invertebrate genera collected in this study were species within the different categories of the Red List of the International Union for Conservation of Nature (IUCN). Among them are found lobsters (*Machrobrachium* genus) and dragon flies (most genera, except *Agriogomphus*). It should be clarified that identification of most organisms did not reach the level of species, given the difficulties implied in such a process.

Several of the collected organisms were found in larval stage and for these there are no taxonomic keys a the species level; moreover, there are larval stages that have not been described so that the determination of whether the collected specimen belongs in the red list is a difficult task.

Of the total macro-invertebrate taxa collected, at least 23 could be considered as not common or of restricted distribution in the country (based on comparisons of the materials found in the Aquatic Entomology collection of the Zoology Museum of the University of Costa Rica). This number corresponds to a third part of the collected taxa, which is a considerable fraction, demonstrating that this region of the country has not been sampled extensively or at least not as much as other regions.

In general, the aquatic community of most sites sampled had a very low diversity and richness of taxa. This results is probably due to three reasons: stream size, turbidity-sedimentation and type of substrate. In rivers of low areas, turbidity values are high as a consequence of sediment drag from medium and upper parts of the watershed, which turns river bottom substrates unstable (Minshall, 1984; Williams and Felmate, 1992; Roldan and Ramirez, 1984). Sediments such as clay and fine sand can alter the movement of water, the quality of nutrients, the availability of oxygen and interstitial spaces, significantly altering the habitat in a substrate (Minshall, 1984)

Chart 17: Description of sites and sampling points along Route 1856.

Site	Location	Photographs	Coordinates /Altitude	Waterway Width/ Depth	Water Speed	Substrate	Solar Radiation Exposure	Comments
1	Upstream		10,98939°N, -84,35498°W, 35 masl	W: 4 m D: 0,25 m	Slow	Gravel	Large openings	Presence of fish, leaf litter, logs, underwater roots and branches. Clean rock surface. Clear water. Pasture and cattle pastures on both margins. Weather condition: sunny.
	Downstream		10,99007°N, -84,35464°W, 36 masl	W: 4 m D: 0,5 m	Slow	Clay	Large openings	Presence of fish, leaf litter, logs, underwater roots and branches. Murky water. Underwater pasture and scrublands on both margins. Weather condition: cloudy.
2 Caño Trinidad	Upstream		10,95466°N, -84,35317°W, 29 masl	W: 15 m D: >1 m	Slow	Clay	Shadow with openings	Presence of fish, leaf litter and underwater roots. Murky water. Underwater pasture, riparian forest and then cattle pasture on both margins. Weather condition: sunny.

Site	Location	Photographs	Coordinates /Altitude	Waterway Width/ Depth	Water Speed	Substrate	Solar Radiation Exposure	Comments
	Downstream		10,95486°N, -84,35281°W, 40 masl	W: 20 m D: >1 m	Slow	Gravel Clay	100% Exposed	Presence of leaf litter and underwater roots. Clean rock surface. Murky water. Pasture, riparian forest and then cattle pastures on both margins. Weather condition: sunny.
3	Upstream		10,94813°N, -84,34488°W, 32 masl	W: 1 m D: 0,5 m	Slow	Mud	100% Exposed	Presence of fish and underwater roots. Murky water. Underwater pasture and cattle pastures on both margins. Weather condition: sunny.
	Downstream		10,94830°N, -84,34493°W, 31 masl	W: 1,5 m D: 0,5 m	Moderate	Pebbles Gravel Clay	100% Exposed	Presence of fish and underwater roots. Murky water. Underwater pasture, scrublands and cattle pastures on both margins. Weather condition: sunny.

Site	Location	Photographs	Coordinates /Altitude	Waterway Width/ Depth	Water Speed	Substrate	Solar Radiation Exposure	Comments
4	Upstream		10,93293°N, -84,33364°W, 26 masl	W: 3 m D: 0,5 m	Slow	Clay	Shadow with openings	Presence of leaf litter, branches, logs and underwater roots. Clear water. Riparian forest and scrubland on both margins. Weather condition: cloudy.
	Downstream		10,93294°N, -84,33337°W, 33 masl	W: 3 m D: 0,25 m	Slow	Pebbles Gravel Clay	Large openings	Presence of fish and underwater roots. Murky water. Riparian Clean rock surface. Pastures and riparian forest on both margins. Weather condition: cloudy.
5	Upstream		10,91335°N, -84,29953°W, 31 masl	W: 1m D: 0,15m	Moderate Slow	Clay	Large openings	Presence of tadpoles, fish, leaf litter, logs and underwater branches. Clear water. Forest on both margins. Weather condition: sunny.

Site	Location	Photographs	Coordinates /Altitude	Waterway Width/ Depth	Water Speed	Substrate	Solar Radiation Exposure	Comments
	Downstream		10,91358°N, -84,29939°W, 29 masl	W: 1 m D: 0,25 m	Fast Moderate	Clay	Large openings	Presence of leaf litter and underwater roots. Murky water. Submerged pasture and scrubland on both margins. Weather condition: sunny.
6	Upstream		10,89144°N, -84,27994°W, 17 masl	W: 2 m D: 0,25 m	Fast	Blocks Pebbles Gravel Sand	Shadow with openings	Presence of leaf litter, logs, underwater roots and branches. Clear water. Clean rock surface. Forest on both margins. Weather condition: cloudy.
	Downstream		10,89238°N, -84,27893°W, 22 masl	W: 1,5 m D: 0,15 m	Fast	Gravel Sand	Large openings	Presence of leaf litter and underwater roots. Clear water. Clean rock surface. Forest on both margins. Weather condition: sunny. Sand and clay falling from riverbed.

Site	Location	Photographs	Coordinates /Altitude	Waterway Width/ Depth	Water Speed	Substrate	Solar Radiation Exposure	Comments
7	Upstream		10,89171°N, -84,27746°W, 55 masl	W: 1 m D: 0,15 m	Fast	Pebbles Gravel Sand	Shadow with openings	Presence of leaf litter, logs, underwater roots and branches. Clear water. Clean rock surface. Forest on both margins as well as flooded vegetation. Weather condition: cloudy.
	Downstream		10,89233°N, -84,,27780°W, 30 masl	W: 1 m D: 0,15 m	Fast	Gravel Sand	Large openings	Presence of leaf litter, logs, underwater roots and branches. Clear water. Clean rock surface. Submerged pastures and scrubland on both margins. Weather condition: cloudy.
8	Upstream		10,87121°N, -84,22561°W, 30 masl	W: 6 m D: > 1 m	Slow	Mud	Large openings	Presence of leaf litter, logs, underwater roots and branches. Murky water. Submerged pastures and cattle pastures on both margins. Weather condition: rainy.

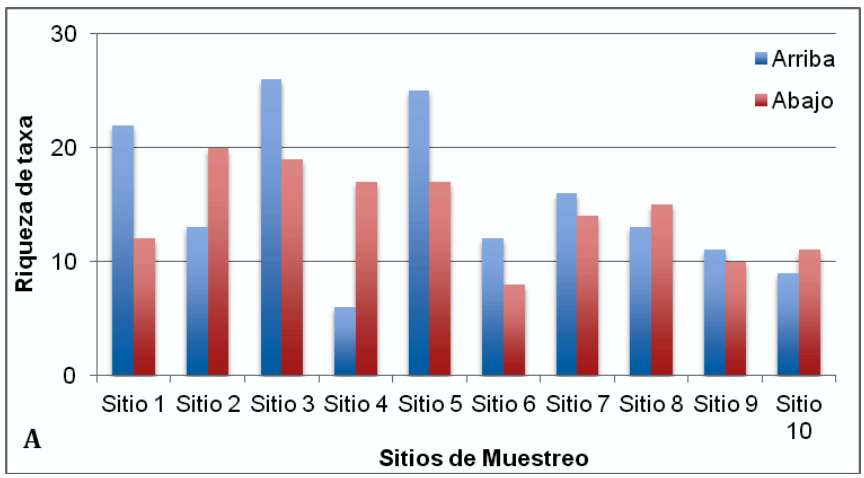
Site	Location	Photographs	Coordinates /Altitude	Waterway Width/ Depth	Water Speed	Substrate	Solar Radiation Exposure	Comments
	Downstream		10,87136°N, -84,22531°W, 35 masl	W: 6 m D: > 1 m	Slow	Mud	100% Exposed	Presence of fish, leaf litter, logs, underwater roots and branches. Murky water. Submerged pastures and cattle pastures on both margins. Weather condition: cloudy.
9 Caño Jardín	Upstream		10,80299°N, -84,22599°W, 31 masl	W: 20 m D: > 1 m	Moderate Slow	Mud	Shadow with openings	Presence of fish, leaf litter, logs, underwater roots and branches. Murky water. Submerged pastures, trees and cattle pastures on both margins. Weather condition: cloudy.
	Downstream		10,80269°N, -84,22574°W, 27 masl	W: 20 m D: > 1 m	Moderate Slow	Mud	Large openings	Presence of fish, leaf litter, logs, underwater roots and branches. Murky water. Submerged pastures, trees and cattle pastures on both margins. Weather condition: cloudy.

Site	Location	Photographs	Coordinates /Altitude	Waterway Width/ Depth	Water Speed	Substrate	Solar Radiation Exposure	Comments
10 Río Marías	Upstream		10,70774°N, -83,91811°W, 26 masl	W: 20 m D: > 1 m	Slow	Mud	Shadow with openings	Presence of fish and leaf litter. Murky water. Submerged pastures, trees and cattle pastures on both margins. Weather condition: cloudy.
	Downstream		10,70854°N, -83,91824°W, 36 masl	W: 20 m D: > 1 m	Slow	Mud	Shadow with openings	Presence of underwater roots and leaf litter. Murky water. Pastures, trees and cattle pastures on both margins. Weather condition: rainy.

Determination of the type of substrate in a stream bed is most important since the establishment of marginal flora and aquatic fauna depends on it. The sandy alluvial and clay substrata are normally found in the lower parts of watersheds, where current is slow. These types of substrate are very poor in bentonic fauna, since they are a very unstable medium for their establishment (Roldan and Ramirez, 2008). The fauna that is dominant in these types of environment is constituted by organisms adapted to low oxygen levels and high quantities of solids such as diptera and some predators such as odonata, coleoptera and hemiptera (Williams and Felmate, 1992).

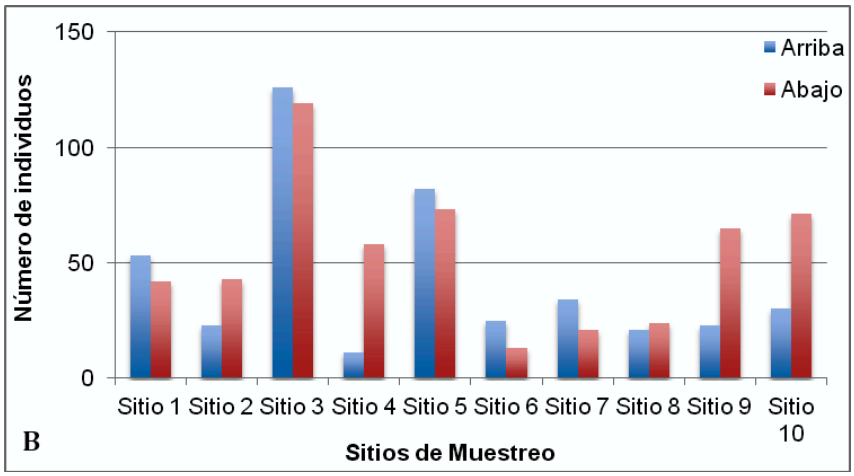
Graph 1 displays the richness of taxa, which was greater in the sample points located upstream from Route 1856, in 6 of the sites sampled. Of these, sites 3 and 5 presented the highest values. In Graph 2 it can be seen that the quantity of individuals varied greatly by site and location along the sampling points, site 3 being the one with the highest values in comparison to the rest.

Graph 1: Richness of taxa in sampled sites.



Riqueza de taza: Richness of taxa
Sitios de muestreo: Sampling points
Sitio: Site
Arriba: Upstream
Abajo: Downstream

Graph 2: Richness (A) and abundance (B) of aquatic macroinvertebrate taxa collected at sites along Route 1856.



Número de individuos: Number of individuals
Sitios de muestreo: Sampling points
Sitio: Site
Arriba: Upstream
Abajo: Downstream

Based on the values of richness and abundance of taxa obtained for the control sites (upstream from the Route) and the influence sites (downstream from the Route) it can be seen that in half of the cases it is possible to affirm that bio-indicators did not present an evident response that would indicate that there has been an impact on the macro-invertebrate communities, since the values obtained are very variable.

A greater taxonomic abundance and richness was expected in control sites (upstream from the Route), which did not turn out to be the case. In sites 5, 6, 7, 8 and 9, located within the segment identified as impacted (Infiernito River to mouth of the San Carlos River), a punctual impact was observed in the community of aquatic macro-invertebrates, where the richness and abundance decreased at the points located downstream from the Route (see Chart 18).

The previous result could be attributed to two factors: 1) the degradation in the quality of the habitat, as a consequence of some activities that were partof the construction of the Route, such as the movement of earth and cutting down of river margin vegetation, 2) the process of sedimentation that occurs in the rivers, due to unstable slopes and landfills that are eroded by rainfall.

Chart18: BMWP-CR' index values and water quality at sampled sites along Route 1856, 2013.

Site	BMWP-CR'Index Value		Water Quality	
	Upstream	Downstream	Upstream	Downstream
1	76	48	Moderate	Low
2	44	62	Low	Moderate
3	72	55	Regular	Low
4	27	50	Very Low	Low
5	84	63	Moderate	Moderate
6	45	34	Low	Very Low
7	66	75	Moderate	Moderate
8	48	55	Low	Low
9	37	20	Low	Very Low
10	33	44	Very Low	Low

Once altered, an aquatic environment is subject to periods of re-colonization that may vary between a few days to several weeks or months, depending on the nature and the reaches of the alteration (Minshall, 1984). The response of bio-indicators to the effects of the construction of Route 1856 on aquatic ecosystems might not have been the expected one, or even resulted imperceptible in some of the sampled sites, possibly because aquatic communities have already recovered.

The field sampling was conducted approximately a year and half after most of the construction works of the Route were developed (road plotting and installation of temporary passing structures); it is probable that during such period of time the communities were able to reach stability. It is also important to take into account that these bodies of water are found in low lying areas where they receive large quantities of sediments all year round, originating in upper parts of the watershed, so that it is expected that aquatic fauna becomes adapted to high levels of sediments in the water (Roldan and Ramirez 2008).

Therefore, the quantity of sediment contributed by works of the Route is not considered to be sufficient to cause a significant impact on the bio-indicators studied in the sampled locations.

5.1.2.3.3 Quality of Water

The results of water quality values, according to the BMWP-CR Index, are presented in Chart 19. The values range between 20 and 84, which corresponds to a moderate to bad quality level. Of the 20 sites sampled, 7 presented a moderate quality, 9 were of a bad quality and the remainder had very bad quality of water. At sites 1, 3, 5, 6 and 9, the quality went down in the downstream sites (with influence of the Route) with a moderate to bad classification and from bad to very bad in comparison to control sites found upstream (with Route influence). It should be noted that most of these sites are found within the impacted segment of the Route.

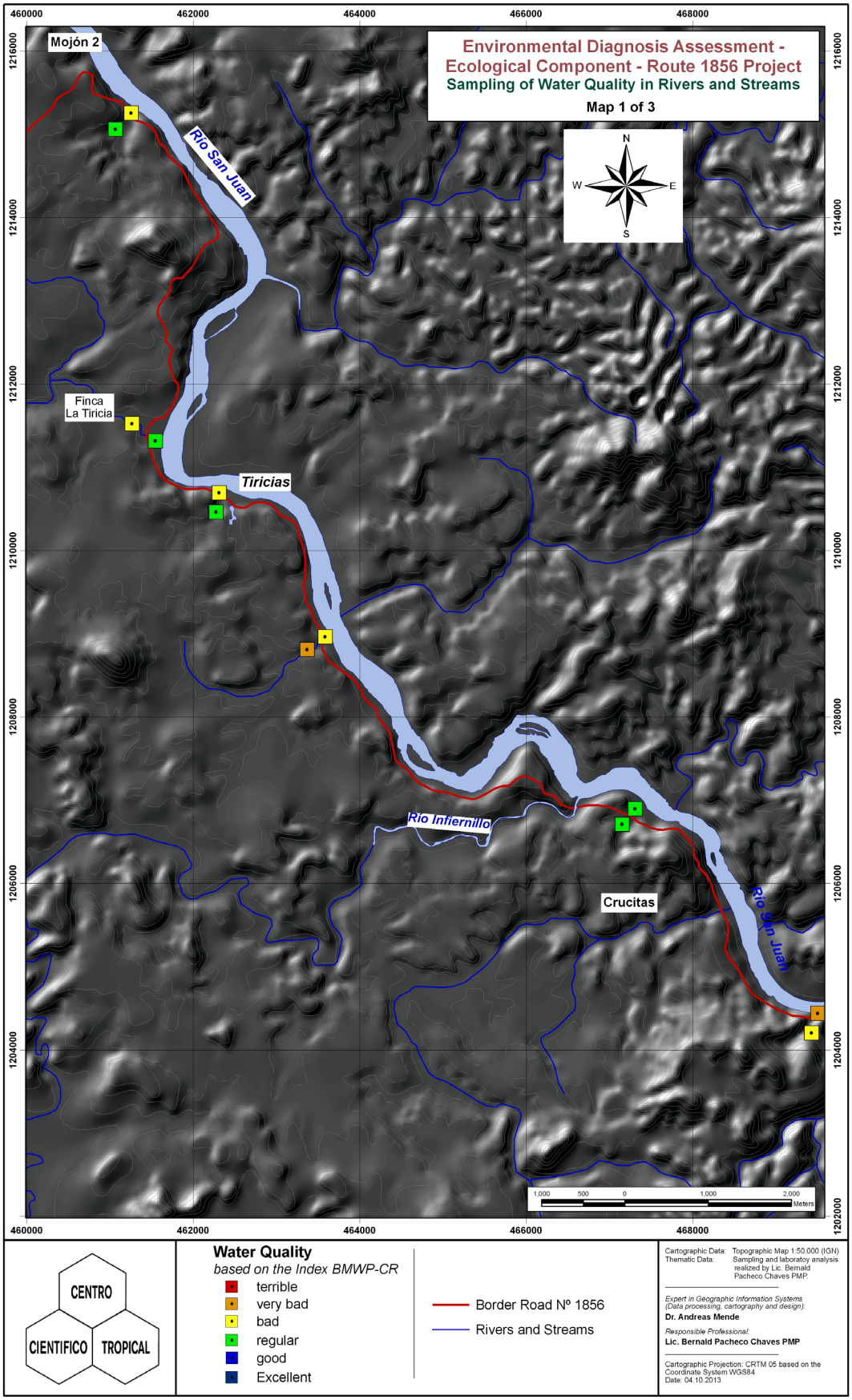
At sites number 7 and 8, the quality of water did not change, staying within the same category while at the remaining sites (sites 2, 4, and 10), the quality increased by one category at a point located downstream from the Route with respect to its corresponding control site (upstream from the Route) (See Map 21, 22 and 23).

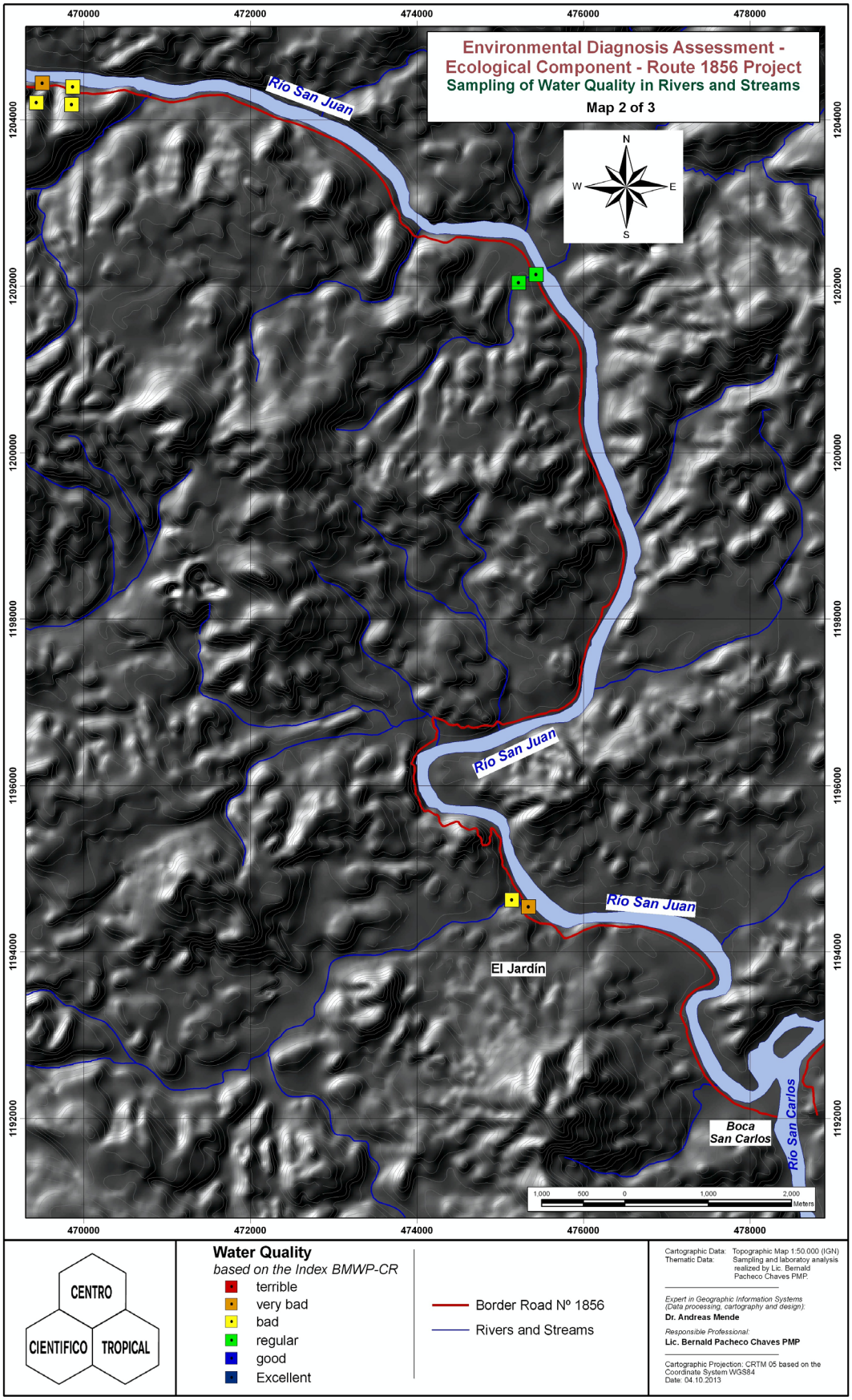
At sites located in the section classified as impacted (Infiernito River-mouth of the San Carlos River), the quality of water was influenced by the works conducted in the Route, as were the richness and abundance of the communities. In Chart 19 and Maps 21, 22 and 23, can be observed that this sites, the value and category of the quality of water goes down, according to the BMWP-CR, suggesting that it might be a reflection of the deterioration of the quality of the habitat (e.g., decrease of availability, heterogeneity and stability of the substratum) and the decrease in the richness of taxa, in response to activities and processes conducted during and after the construction of the Route, such as the movement of earth, tree cutting, erosion and sedimentation.

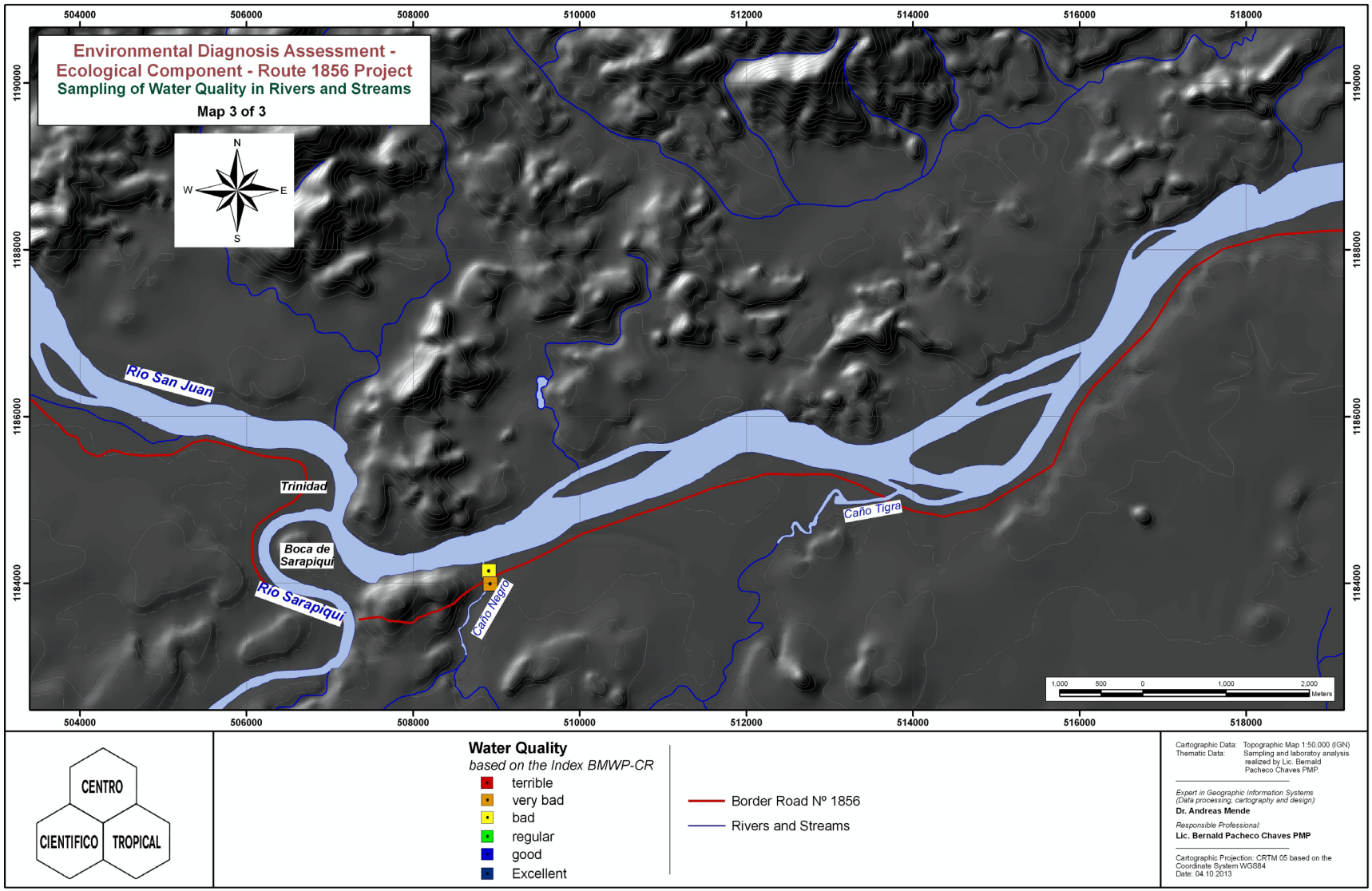
In those instances where the point located downstream improved by one category or remained the same, this could be representing the resilience of the community, the time period since the works were conducted, the re-colonization capacity and the aquatic fauna adaptation skills to bodies of water that should naturally present high levels of sediment content due to their location in the lower part of the watershed.

Chart19: Water quality classification according to BMWP-CR Index.

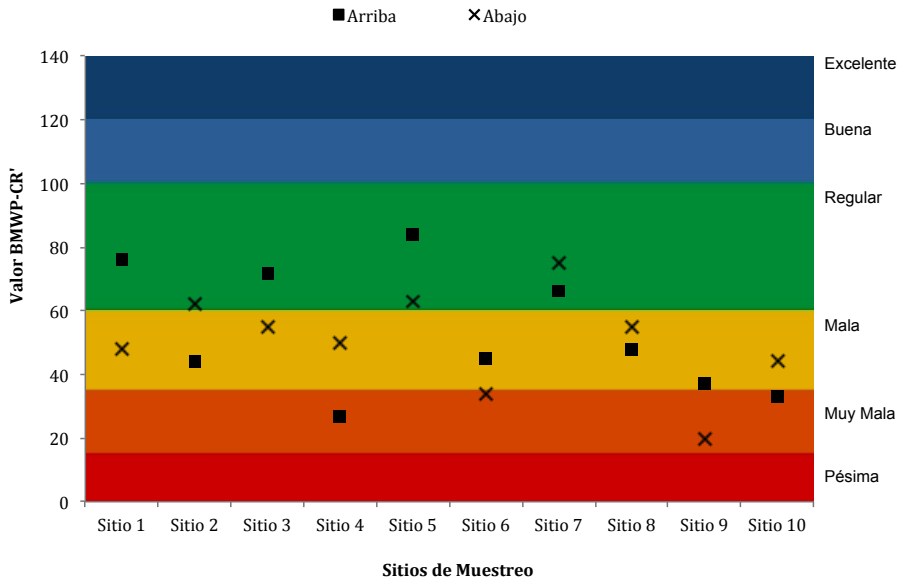
BMWP-CR' Value	*Water Quality*	*Quality Level*	*Color*
>120	Excellent	Waters of excellent quality	**Blue**
101-120	Good	Good quality, not contaminated or altered.	**Blue**
61-100	Moderate	Moderate quality, eutrophic, moderate contamination	**Green**
36-60	Low	Bad quality, contaminated	**Yellow**
16-35	Low	Bad quality, very contaminated	**Orange**
<15	Very Low	Very bad quality, extremely contaminated	**Red**


Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Sampling of Water Quality in Rivers and Streams
Map 1 of 3
N
W
E
S
460000
462000
464000
466000
468000
1216000
1214000
1212000
1210000
1208000
1206000
1204000
1202000
Mojón 2
Rio San Juan
Finca
La Tiricia
Tiricias
Rio Infiernillo
Crucitas
Rio San Juan
1,000 500 0 1,000 2,000
Meters
CENTRO
CIENTIFICO
TROPICAL
Water Quality
based on the Index BMWP-CR
terrible
very bad
bad
regular
good
Excellent
Border Road Nº 1856
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Sampling and laboratoy analysis realized by Lic. Bernald Pacheco Chaves PMP.
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Sampling of Water Quality in Rivers and Streams
Map 2 of 3
N
W
E
S
Río San Juan
Río San Juan
Río San Juan
El Jardín
Boca
San Carlos
Río San Carlos
470000
472000
474000
476000
478000
1204000
1202000
1200000
1198000
1196000
1194000
1192000
1,000 500 0 1,000 2,000
Meters
CENTRO
CIENTIFICO
TROPICAL
Water Quality
based on the Index BMWP-CR
terrible
very bad
bad
regular
good
Excellent
Border Road Nº 1856
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Sampling and laboratoy analysis realized by Lic. Bernald Pacheco Chaves PMP.
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Sampling of Water Quality in Rivers and Streams
Map 3 of 3
N
W
E
S
504000
506000
508000
510000
512000
514000
516000
518000
1190000
1188000
1186000
1184000
Rio San Juan
Trinidad
Boca de Sarapiquí
Río Sarapiquí
Caño Negro
Caño Tigra
1,000 500 0 1,000 2,000
Meters
CENTRO
CIENTIFICO
TROPICAL
Water Quality
based on the Index BMWP-CR
terrible
very bad
bad
regular
good
Excellent
Border Road Nº 1856
Rivers and Streams
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Sampling and laboratoy analysis realized by Lic. Bernald Pacheco Chaves PMP.
Expert in Geographic Information Systems (Data processing, cartography and design):
Dr. Andreas Mende
Responsible Professional:
Lic. Bernald Pacheco Chaves PMP
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

Graph3: Water quality values according to BMWP-CR' Index of the sampled sites along the Route 1856 "Juan Rafael Mora Porras", July - August, 2013.



Valor BMWP-CR: BMWP-CR Value
Sitios de Muestreo: Sampling Sites
Arriba: upstream
Abajo: downstream.
Excelente: Excellent
Buena: Good
Regular: Moderate
Mala, Muy Mala: Low
Pésima: Very Low

The BMWP-CR index works on the basis of the presence of families or groups of macro-invertebrates which are given points (one to nine) according to their sensitivity to alterations in their environment, so that organisms with greater sensitivity obtain higher points while those more tolerant receive lower points. Some of the families found in this study are considered sensitive and therefore they obtain high points. Among them can be mentioned: Blaberidae (Dictyoptera), Calamoceratidae, Glossosomatidae, Leptoceridae (Trichoptera), Lepthophlebiidae, Heptageniidae (Ephemeroptera) Perlidae (Plecoptera), Gomphidae, Megapodagrionidae, Platystictidae, Protoneuridae, Corduliidae and Polythoridae (Odonate), Psephenidae and Ptilodactylidae (Coleoptera).

The presence of groups sensitive to alterations of the aquatic habitat is a good signal, since these indicators usually disappear in cases of strong alteration of the aquatic habitat, especially if the effect is persistent through time, because it does not allow sensitive taxa to re-colonize the bodies of water. The finding of sensitive families in practically all sampled sites, and in points above and below the road, may be interpreted as a positive signal of recovery and of lesser impact of the road works on the environmental conditions a the points under study. Only the sites number 9 (below) and 10 (above) did not present sensitive macro-invertebrates.

Comparing the results of the present study with those obtained by Salvatierra et al. (2012), in the study "Establishing the Environmental Base Line of the San Juan River- Nicaragua- 2013" where during the two seasons of 2012 (rainy and dry), 38 aquatic macro-invertebrates were collected in 20 sampling stations located along the San Juan River and tributaries (9 of them in the stretch between Border Mark 2 and Delta Costa Rica), it can be affirmed that the richness of families (58) and genera (73) collected in the present study is superior.

The difference in sampling method could be one of the factors that influence the results. According to Roldan and Ramirez (2008), the diversity of macro-invertebrates is greater along the margins of bodies of water and decreases with depth. In the study by Salvatierra et al.(2013) two sampling methods were used to collect aquatic organisms (dredging and artificial substrata), both of them collecting organisms from the river bottom.

These two methods are frequently used in rivers of large size, great depths and very big volume, such as the San Juan River, and in *lentic* habitats such as lakes and lagoons. The rivers sampled in this study are tributaries of the San Juan, so that their characteristics are very different and consequently the results obtained and the methods used were also very different (our direct sampling was done with D nets in the margins and at depths no greater than one meter).

In the same study, Salvatierra et al. (2013) applied a water quality index (IBF adapted to El Salvador) and obtained four categories of water quality; very poor, poor, moderately poor and moderate. It should be pointed out that none of the 9 stations that was within the section of the study obtained a moderate quality of water. The IBF-SV works differently from the BMWP-CR, where the first one takes into account the abundance and number of families present and the second one only uses the number of families.

Also to be pointed out is the fact that the sampling of bio-indicators was done in tributaries of the San Juan River, so that impacts detected due to the Route works on the aquatic environment, such as modification of substratum and sedimentation, are of a local level. The present study had the limiting condition that it was not allowed to take samples in the San Juan River, so that impacts detected were in rivers in Costa Rican territory.

These bodies of water were the ones which received a direct influence from the road works, and the results obtained do not overlap to the San Juan River, since the San Juan is of a superior order, with a much greater volume than the rivers that were sampled. The stretch of the San Juan River which runs parallel to this road, is found in the lower part of the watershed, where the quantities of sediment are normally high (Roldan and Ramirez, 2008), which leads to the consideration that impacts from the Route on organisms that inhabit the San Juan could have been minimal and very diffuse, considering the high volume of that river.

Furthermore, evaluating the impacts that could have been produced by the construction of the Route on the aquatic biota of the San Juan River would have been extremely difficult especially because there are other factors that determine environmental conditions and diversity of species in the river. Within these, the following can be mentioned: the rainfall (which varies from rainy to dry season), the volume, depth, land use in the upper, medium and lower levels of the sub-watersheds that empty into the San Juan, both in Costa Rica and in Nicaragua, and which are exposed to anthropogenic activities.

Finally, another factor that must be taken into account is the adaptation capacity of aquatic organisms in the natural conditions of the river, because due to having their habitat in the lower level of the watershed, they have a degree of adaptation to those conditions in particular.

The season and time were limiting conditions on the study, since the study lasted only 4 months, taking place during the rainy season of the Caribbean Coast. It was not possible to do sampling during the short dry spells common in this part of the country. The time available for the study limited the number of sites to be sampled, since it was necessary to select some bodies of water to conduct bio-indicator analyses but it was not possible to sample all bodies of water located along the Route, and thus the results are limited to the sample and do not to the total number of such bodies. The sampling effort was greatest in the critical stretch of the Route, based on recognition of the Project area, which concluded that this stretch would be the most indicated to measure impacts.

5.1.2.4 Endemic Species with Reduced or Threatened Populations

The presence of endangered or highly threatened species in the study area is a condition that justifies protecting the riparian ecosystems. These species have been affected mainly by the reduction of habitat as a consequence of deforestation and the fragmentation of forests.

In the list of species obtained through bibliographic review, 59 species of aquatic fauna were found to be included in some special conservation category according to the official lists of the CITES convention of the IUCN and the Law on Conservation of Wild Life, which adds additional value to the appropriate management of natural resources in the region. Chart 20 presents a list of the aquatic species in the region, aimed at promoting their conservation.

Chart20: Species of aquatic fauna recorded for the project area included, included in some conservation category

.Family	Species	Conservation Status		
		CITES[a]	IUCN[b,c]	SINAC
FISHES				
Carcharhinidae	*Carcharhinus leucas*		NT	
Characidae	*Hyphessobrycon tortuguerae*		LC	
Cichlidae	*Parachromis friedrichsthalii*		LC	
Megalopidae	*Megalops atlanticus*		VU A2bd	
Pristidae	*Pristis pectinata*		CR A2cd	
	Pristis perotteti		CR A2abcd	
MAMMALS				
Mustelidae	*Lontra longicaudis*	Appendix I	DD	PRA
Trichechidae	*Trichechus manatus*	Appendix I	VU C1	PE
Tapiridae	*Tapirus bairdii*		EN A2abcd+3bce	PE
Didelphidae	*Chironectes minimus*		LC	
ANFIBIOS				
Leptodactylidae	*Leptodactylus melanonotus*		LC	
	Leptodactylus labialis		LC	
Ranidae	*Rana taylori*		LC	
	Rana vaillanti		LC	

.Family	Species	Conservation Status		
		CITES[a]	IUCN[b,c]	SINAC
REPTILES				
Iguanidae	*Iguana iguana*	Appendix II		
Chelydridae	*Chelydra serpentina*		LC	
Geoemydidae	*Rhinoclemmys funerea*		MR / NT	
Crocodylidae	*Caiman crocodilus*	Appendix I	MR / NT	
	Crocodylus acutus	Appendix I	VU A2cd	PE
BIRDS				
Alcedinidae	*Chloroceryle aenea*		LC	
	Chloroceryle amazona		LC	
Alcedinidae	*Chloroceryle inda*		LC	PRA
Anatidae	*Anas acuta*		LC	
	Anas clypeata		LC	
	Anas crecca		LC	
	Anas cyanoptera		LC	
	Anas discors		LC	
	Aythya affinis		LC	
	Aythya callaris		LC	
	Cairina moschata		LC	PARA
	Dendrocygna autumnalis		LC	
	Dendrocygna viduata		LC	PE
	Oxyura dominica	Appendix II		PRA
Anhingidae	*Anhinga anhinga*		LC	
Ardeidae	*Agamia agami*		VU A3c	PRA
	Ardea herodias		LC	
	Botaurus pinnatus		LC	PRA
	Casmerodius albus		LC	
	Egretta caerulea		LC	
	Egretta thula		LC	
	Egretta tricolor		LC	
	Tigrisoma fasciatum		LC	
	Tigrisoma lineatum		LC	
	Tigrisoma mexicanum		LC	

.Family	Species	Conservation Status		
		CITES[a]	IUCN[b,c]	SINAC
Ciconiidae	*Jabiru mycteria*	Appendix I	LC	PE
	Mycteria americana	Appendix I	LC	
Heliornithidae	*Heliornis fulica*		LC	PE
Podicipedidae	*Podilymbus podiceps*		LC	
	Tachybaptus dominicus		LC	
Scolopacidae	*Limnodromus scolopaceus*		LC	
	Tringa solitaria		LC	
Rallidae	*Amaurolimnas concolor*		LC	
Threskiornithidae	*Eudocimus albus*		LC	
	Mesembrinibis cayennensis		LC	PARA
	Plegadis chihi		LC	
	Plegadis falcinellus		LC	
CRUSTACEA				
Palaemonidae	*Macrobrachium carcinus*		LC	
	Macrobrachium acanthurus		LC	
	Macrobrachium olfersi		LC	

Extinct (EX), Extinct in the Wild (EW), in Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened(NT), Least Concern (LC), Data Deficient (DD), Not evaluated (NE), Minor Risk (MR), Limited or Threatened Populations (PRA), In Danger of Extinction (PE).

Source: CITES, 2013; IUCN, 2013; MINAE, 2005.

Notes:

[a] Appendix I includes threatened species. The commerce of individuals of these species is permitted under exceptional circumstances

Appendix II includes species that are no necessarily under threat but whose commerce must be controlled toavoid uses that are incompatible with their survival.

Appendix III contains the species that are protected at least in one country, which has requested help from other members of the CITES to control their commerce.

[b] Vulnerable

A. Reduction of population size based on any of the following points:

1. The population has experienced an observed, estimated, inferred or suspected reduction of ≥ 50% in the last 10 years or in three generations, depending on which is the longest period, during which it is possible to show that the causes of the decrease are clearly reversible and understood and that they have ceased, based on and in compliance with at least one of the options (a) to (e).

2. The population has experienced an observed, estimated, inferred or suspected reduction of ≥ 30% during the last 10 years or three generations, depending on which is the longest period, where this reduction or its causes may have ceases or may not be understood, or may not be reversible base don and in compliance with one of the options (a) to (e).

3. A reduction of the population ≥ 30% that is projected or suspected of being reached within the next 10 years or three generations, depending on which is the longest period (for a maximum of 100 years) based on at least one of the options (b) to (e).

(a) Direct observation

(b) An indexof abundance appropriate for the taxon

(c) A decrease in the occupation area, a reduction in extension of presence and or the quality of the habitat.

(d) Levels of real or potential exploitation.

(e) The effect of introduced taxa, hybridization, pathogens, contaminants, competitors or parasites.

C. Size of estimated population of less than 10,000 mature individuals.

1. An estimated continuous decrease of, at least, 10% in a period of ten years, or three generations, whichever is the longest period (up to a maximum of 100 years in the future).

[c]Endangered

A. Reduction in the size of the population based on any of the following:

2. The population has experienced an observed, estimated, inferred or suspected reduction ≥ 50% in the last 10 years or three generations, depending on which is the longest period, where such reduction or its causes may not have stopped or may not be understood, or not be reversible, based on the compliance with one of the options (a) to (e).

3. A reduction of the population ≥ 50% that is projected or suspected of being reached within the next 10 years or three generations, depending on which is the longest period (for a maximum of 100 years) based on compliance with at least one of the options (b) to (e).

(a) Direct observation

(b) An indexof abundance appropriate for the taxon

(c) A decrease in the occupation area, a reduction in extension of presence and or the quality of the habitat.

(d) Levels of real or potential exploitation.

(e)The effect of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

5.1.2.5 Fragility of the Inland Aquatic Environment.

5.1.2.5.1 Ecosystem Fragility

Fragile ecosystems are understood to be those that are sensitive to human alterations or extreme natural events and that do not recover easily. Among fragile ecosystems that can be found in the study area are the forested areas and the bodies of water such as lagoons, rivers and creeks.

The presence of a diverse and abundant fauna of aquatic macro-invertebrates is important for the river, due to the fact that they provide basic functions to the ecosystem. On the one hand, they are important to the recycling of organic materials and nutrient cycles of the river since many of them feed off the leafy material that falls in the river, while others are filters of fine organic material in suspension thus providing a basic function in the self-recovery of the river and improvement of the quality of the water. On the other hand, macro-invertebrates are an important part of the food chains, both for aquatic species such as fish, and for terrestrial species (birds, bats, amphibians, some reptiles, spiders and other insects.)

The activity and the transit of machinery on river beds destroy the micro-habitats and cause the release of *bentonic* organisms which are then dragged downstream. Also the cutting of river edge vegetation can have a negative effect on the aquatic fauna, due to the decrease of leafs and submerged roots that implies a lesser quantity of food and less diversity of micro-habitats.

Moreover, construction works can potentially provoke contamination due to hydrocarbons and oils, and solid waste among other, which decreases considerably the quality of water at the site and downstream.

All of these effects can become more pronounced in conditions when the water level is low, especially during the dry season. When the volume of water is lower, the dilution of sediments is less, and the negative impact is greater.

Some impacts occasioned by the construction of highways on the creeks have been identified by other authors, as follows: an increase in the non-organic sediments due to the erosion of river margins which have been deforested, an increase in erosion of land surfaces due to contouring and levelling of the land and the alteration of the natural course of the stream due to re-alignment necessary when placing gutters and building bridges (King and Ball, 1965; Duck 1985; Johnson 2002, 2006; Urban and Rhoades 2003; Wohl 2000, 2006, in Hedrick, 2008)

Construction projects are often implemented in a short period, so that recovery of a body of water from the deposition of sediments and the levels of solid matter in suspension may return to conditions similar to those present before the construction (Barton 1977 in Hedrick 2008) which is contrary to the case of agricultural production, which is considered a permanent use of land and which constantly provides sediments to the bodies of water. Cline et al, (1982 in Hedrick, 2008), evaluated the response of a creek to the construction of a road over a three year period in a rocky mountain elevation.

The solids and sediments suspended increased in the impacted study sites. Nevertheless the values in impacted sites approximated those of reference sites within two years after the end of construction. The density of *bentonic* macro-invertebrates in the impacted sites were less than those in reference sites during and immediately after the construction.

After one year of construction, the values were comparable to those of reference sites. The taxa most intolerant to the effects of the road construction were the orders Ephemeroptera, Plecoptera and Trichoptera; nevertheless, it is necessary to point out that this study was performed in conditions different to those of Route 1856 in another latitude and altitude, therefore the results of this study cannot be applied to those in the area of the Route project.

5.1.2.5.2 Buffer Areas

It is very important that mitigation actions take into account the conservation of the vegetation on the edges of bodies of water, which according to Forestry Law No. 7575 must keep a protection zone on the margins of rivers, creeks and streams, of 15 meters if the terrain is flat and 50 horizontal meters if the land is hilly.

In addition, there must be a protection zone with a radius of 100 horizontal meters for permanent water springs, and a protection zone of 50 meters for lakes and dams, natural or artificial, the latter being limited to state property, and in areas of water recharge and aquifers of springs, in which case the limits are determined by competent organs established by Law.

It is important that the construction project take into account the reforestation of river margin areas which have been deforested, using native species from the region, in addition to the river margins along the Route which had been impacted before the construction by human activities.

5.1.2.5.3 Adaptation to Sedimentation

The transportation of sediments and sedimentation are natural processes in the lotic aquatic environments that play an important role in the structuring of river habitats (Connolly and

Pearson 2007). The aquatic systems of the lower topography generally have greater levels of sedimentation due to their downstream location and anthropogenic perturbation. Nevertheless, the accelerated degradation, contamination and the high level of sedimentation in aquatic bodies are the main problems that lead to the loss of aquatic diversity at a global level (Hedrick 2008).

The increase in sediment load may affect aquatic ecosystems in a variety of ways depending on the form, size and density of the particles. Frequently the increase in transportation and deposition of sediments are a consequence of anthropogenic activities such as agriculture, civil engineering projects and extractive industries (silvi-culture and mining) (Connolly and Pearson 2007).

The effects of sediments on bentonic macro-invertebrates and fish in streams are very diverse. Some species of macro-invertebrates and fish have learned through time to adapt to certain conditions of high sedimentation. The aquatic fauna of low areas is very tolerant to sedimentation even when exposure is more than 15 days (Connolly and Pearson 2007).

However, the excessive sedimentation in creeks may alter the composition and abundance of aquatic biota (Rabeni and Samie, 1995; Jones et al, 1999 in Hedrick, 2008) decreasing the reproductive effect and the survival of fish. For instance, most bentonic macro-invertebrates inhabit the bottom of rivers and are sensitive to changes in the environment. Many fish feed off bentonic invertebrates and when there are alterations in the medium due to the deposition of sediments, the abundance of *bentonic* organisms diminishes and, as a consequence, the food available to the fish decreases, (Lemly 1982; Scrivener and Brownlee 1989; O´Conner and Andrew 1998; Sweka and Hartman, 2001 in Hedrick 2008; Waters, 1995 in Hedrick 2008).

Values reported in the literature consulted about the effect of the sedimentation on aquatic fauna refers to studies conducted in other countries ((Bruton, 1985; Alabaster & Lloyd, 1980; Bruton, 1985; Wood & Armitage 1997, Packer *et al.* 2005, Melton 2009; Mol & Ouboter, 2003; Rabeni *et al.*, 2005;Connolly & Pearson, 2007; Hedrick, 2008; Wagenhoff *et al.,* 2012; Wohl & Carline, 1996, in Hedrick, 2008; Ryan, 1991; Kaller & Hartman, 2004; Downes *et al.,* 2006; Springer *et al.,* 2010). However, in the present study, it has not been possible to generate the necessary information to determine the threshold of the sedimentary load and its possible effects on the aquatic fauna of the study area.

In order to evaluate with greater certainty if the works on Route 1856 created a level of sedimentation that could have an effect on the aquatic fauna of the San Juan River and its tributaries in the area of this study, it is first necessary to determine and validate the thresholds of sedimentation that could affect the species found in these rivers, since there is no information for aquatic organisms in the area of the study.

5.1.2.5.4 Morbidity and Mortality Thresholds

The values reported in the literature reviewed are based on data obtained in studies conducted in other countries for small rivers of first and second order; rivers that are characterized as being very shallow with a strong current. The San Juan River is relatively deep and of great volume, and therefore could be classified as a 5th or 6th order river. Therefore the values established in studies performed in other countries cannot be used to affirm that the quantities of sediment that enter the San Juan River could have an impact on it.

In order to be able to evaluate with greater certainty if the works on Route 1856 had an effect on the aquatic fauna of the San Juan River and its tributaries, first it is necessary to determine and validate thresholds for morbidity and mortality of the species that are found in these rivers, as

well as the levels of tolerance to sedimentation since there is no information for aquatic organisms in the study area.

In order to establish such values, it would be necessary to conduct periodic analysis over a long term period to evaluate tolerance capacity of fish and macro-invertebrates to different quantities of sediment, and be able to determine the point at which aquatic organisms start to die or experience a significant reduction in abundance and diversity.

6 ENVIRONMENTAL DIAGNOSTIC

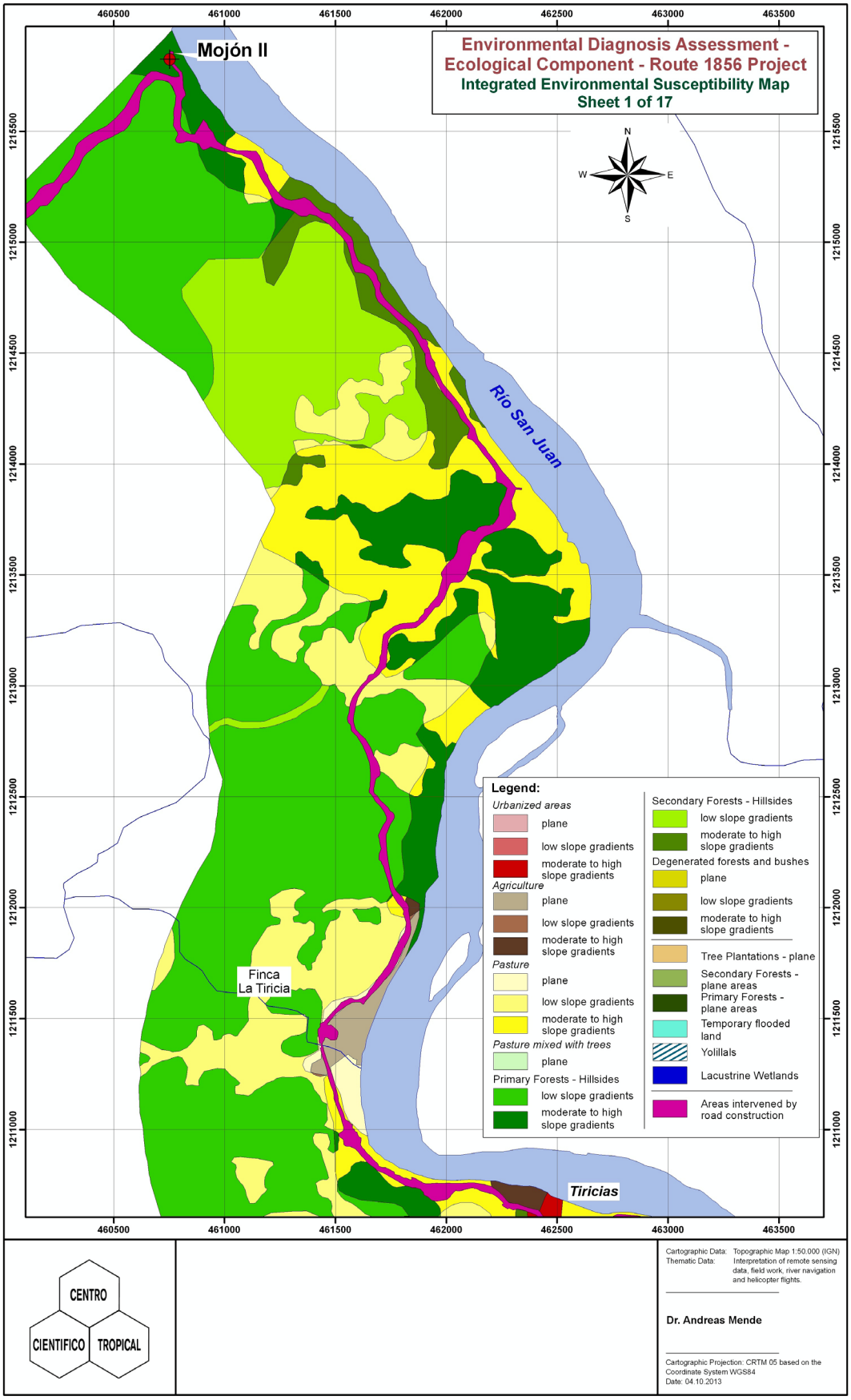
6.1 Comprehensive environmental susceptibility map vs.Project components.

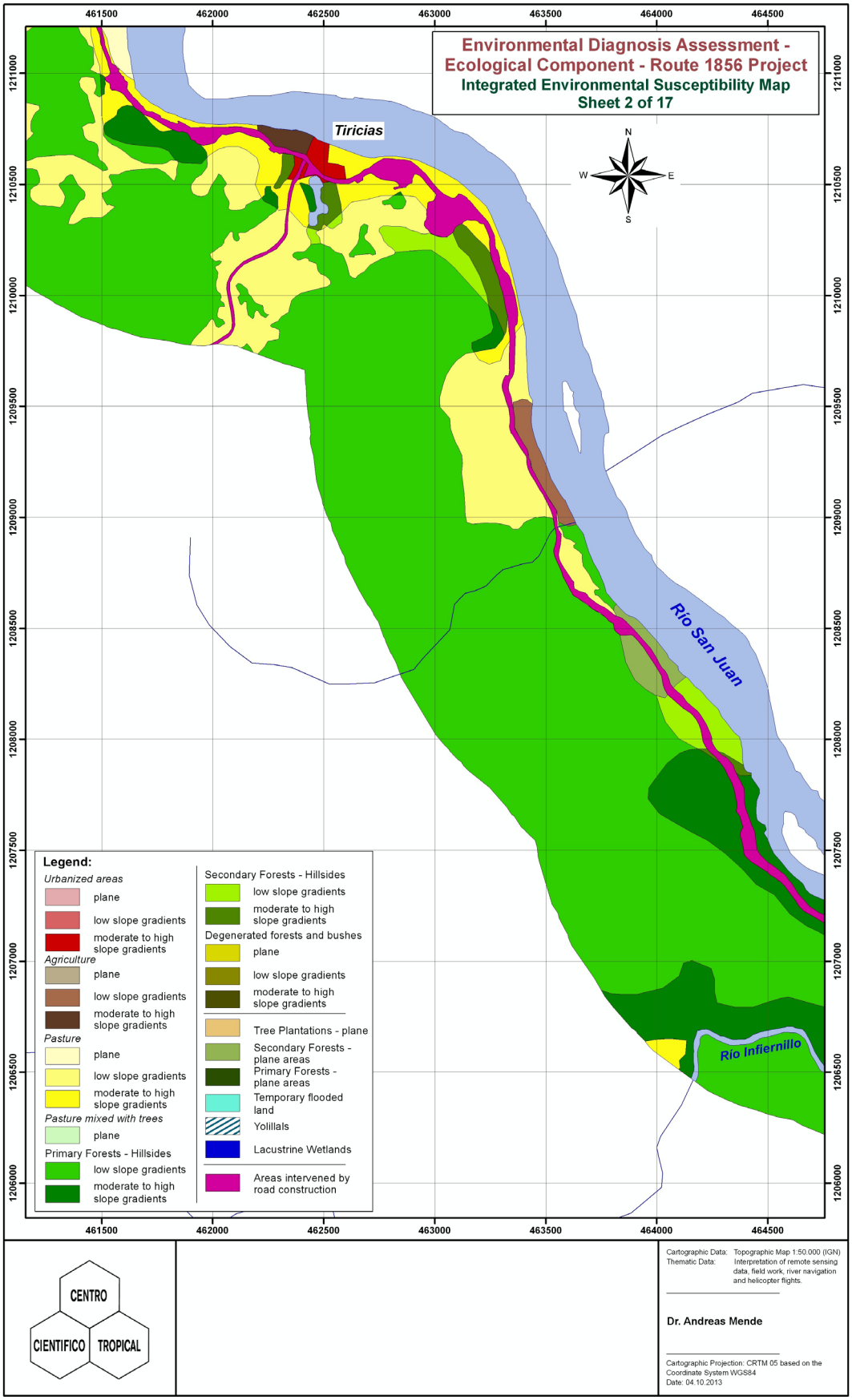
This section exhibits 17 maps on a 1:10,000 scale (in geographic order from Border Marker 2 to the site of Delta Costa Rica) that present an environmental Diagnostic of the influence area of Route 1856. The maps summarize graphically the environmental conditions along the designated path of the Route and emphasize the ecological components identified in previous chapters, using data on the types of land use, combined with different kinds of slopes observed in the area of the Project, imposed on the path of the Route.

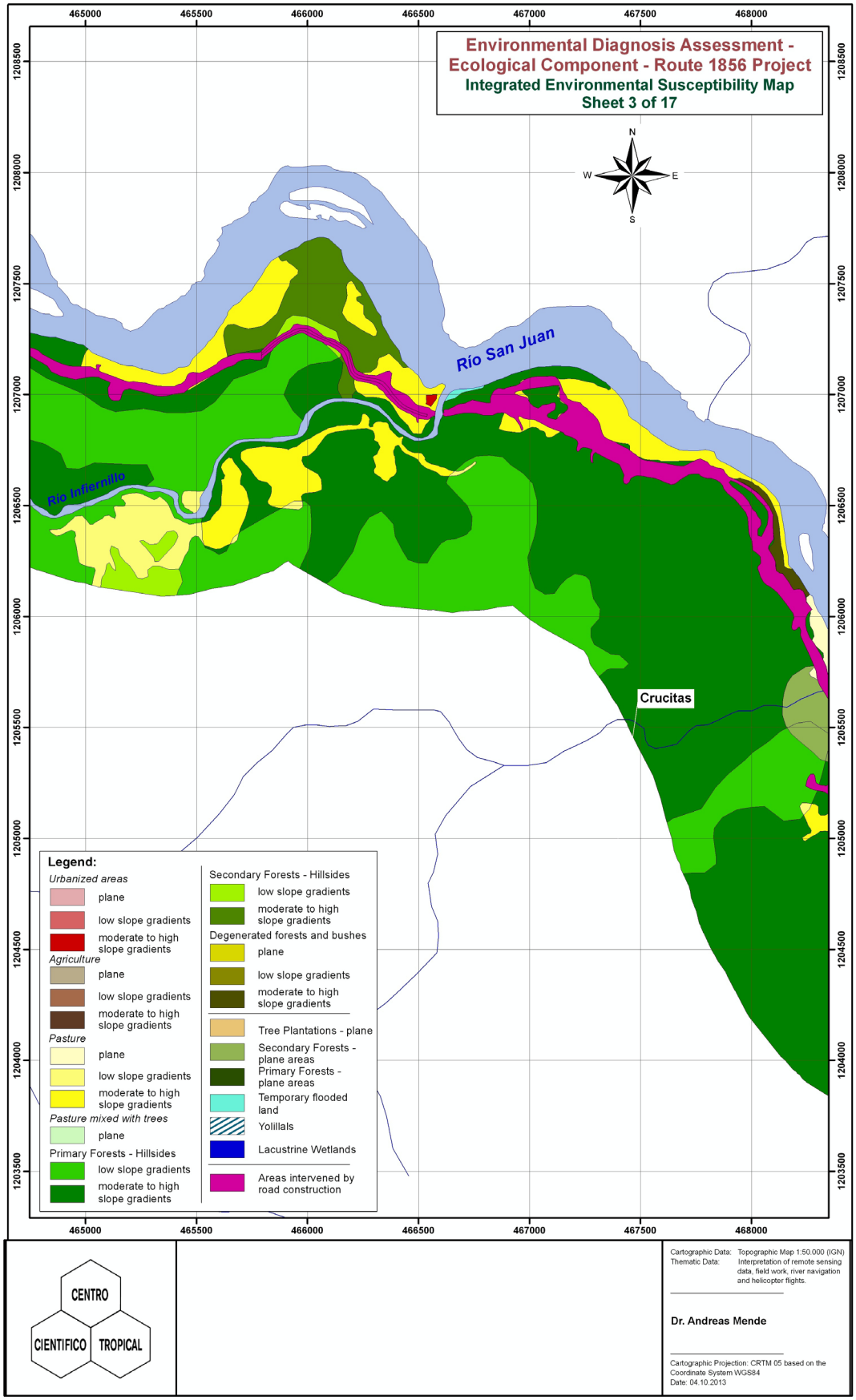
Following are the symbols of the factors analyzed in the maps:

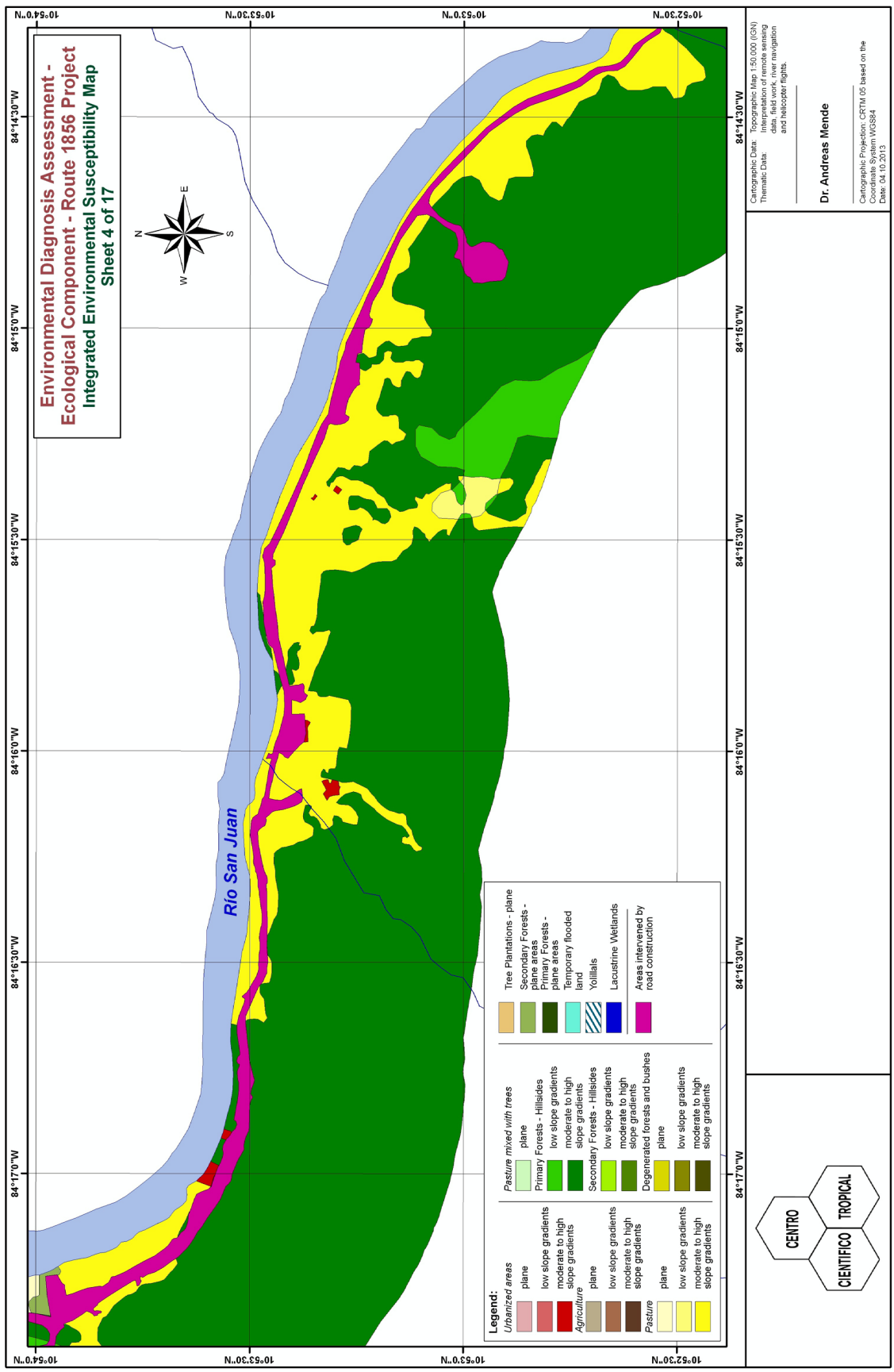
Zonas urbanizadas: Urban zones; Cultivos: Agricultural lands; Pastos: Pastures; Pastos mezclados con arboles: Pasture with trees; Bosque Primario de Ladera: Primary Forest on sloping terrain; Bosque secundario de ladera: Secondary Foresto on sloping terrain; Charrales: Scrubland; Bosque degenerado: Degenerated Forest; Plantaciones de arboles: Tree plantations; Bosque Secundario de Planicie: Secondary Forest in plain terrain; Bosque Primario de Planicie: Primary Forest in plain terrain; Zonas temporalmente inundadas: seasonal flooded areas; Yolillales: Yolillo patches; Humedales lacustrinos: lacustrine wetlands; areas intervenidas: intervened areas.

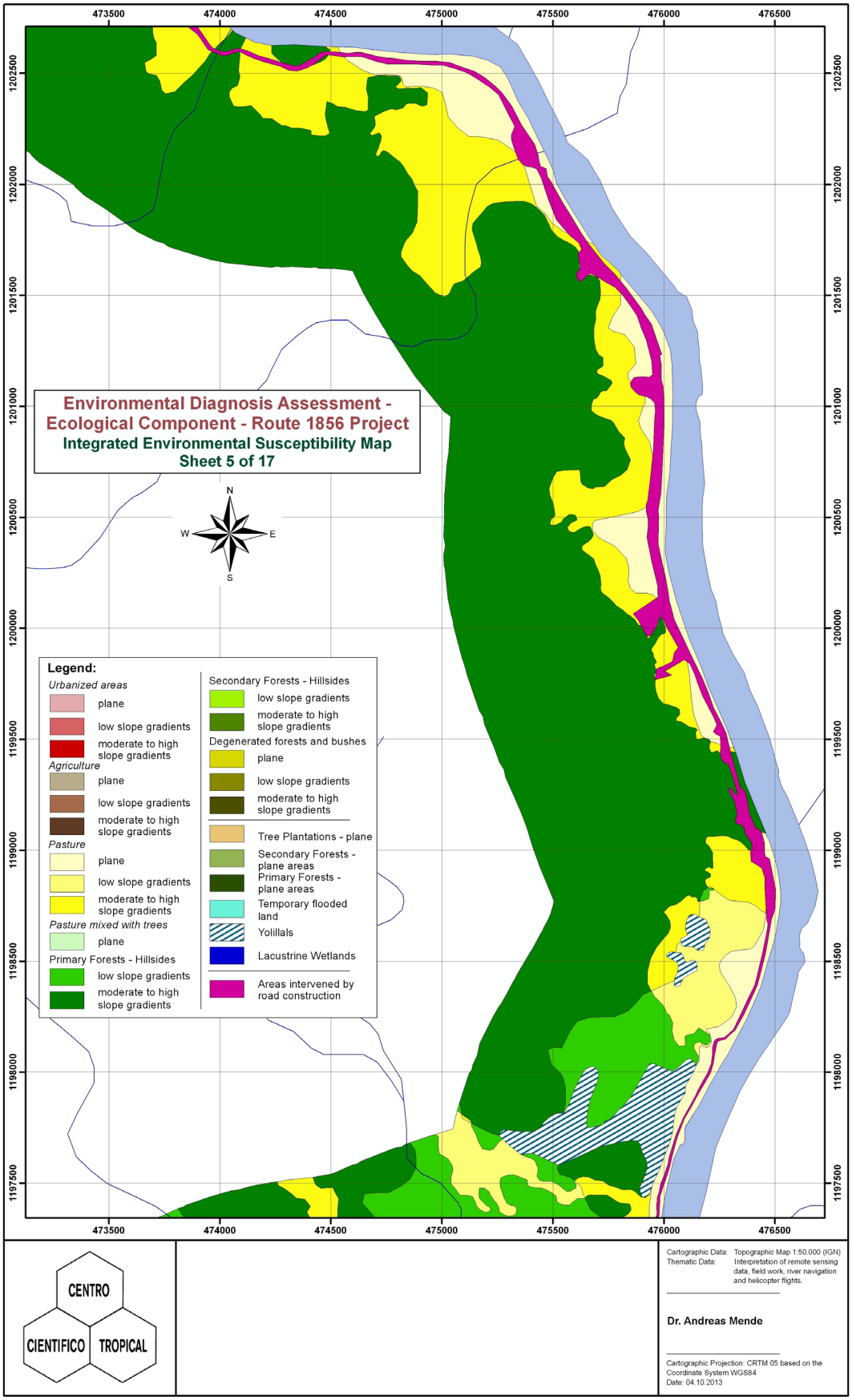
Plano: plain; Pendiente bajo: small slope; Pendiente moderado a alto: moderate to steep slope.

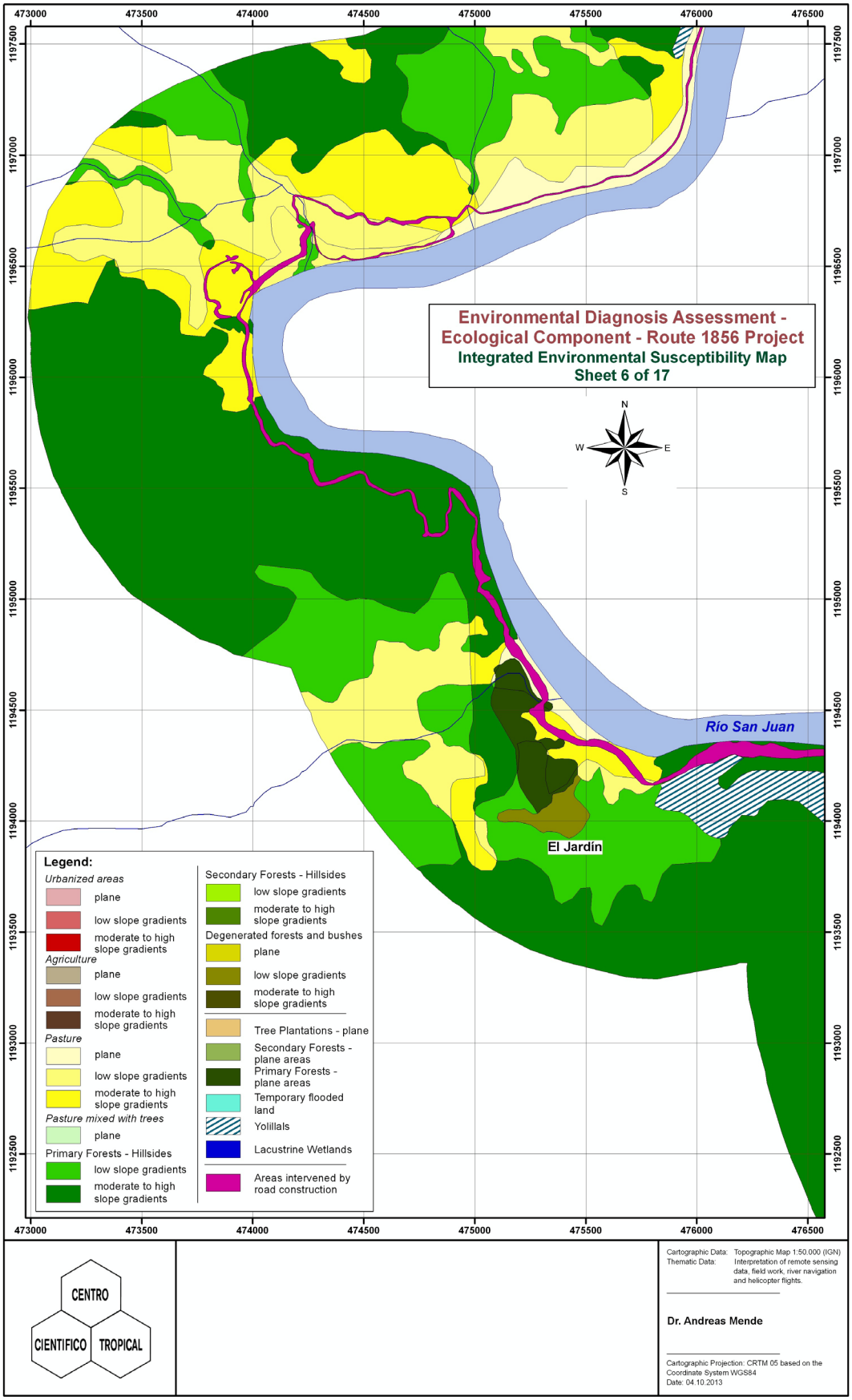

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 1 of 17
Mojón II
Río San Juan
Finca La Tiricia
Tiricias
N
W
E
S
460500
461000
461500
462000
462500
463000
463500
1215500
1215000
1214500
1214000
1213500
1213000
1212500
1212000
1211500
1211000
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

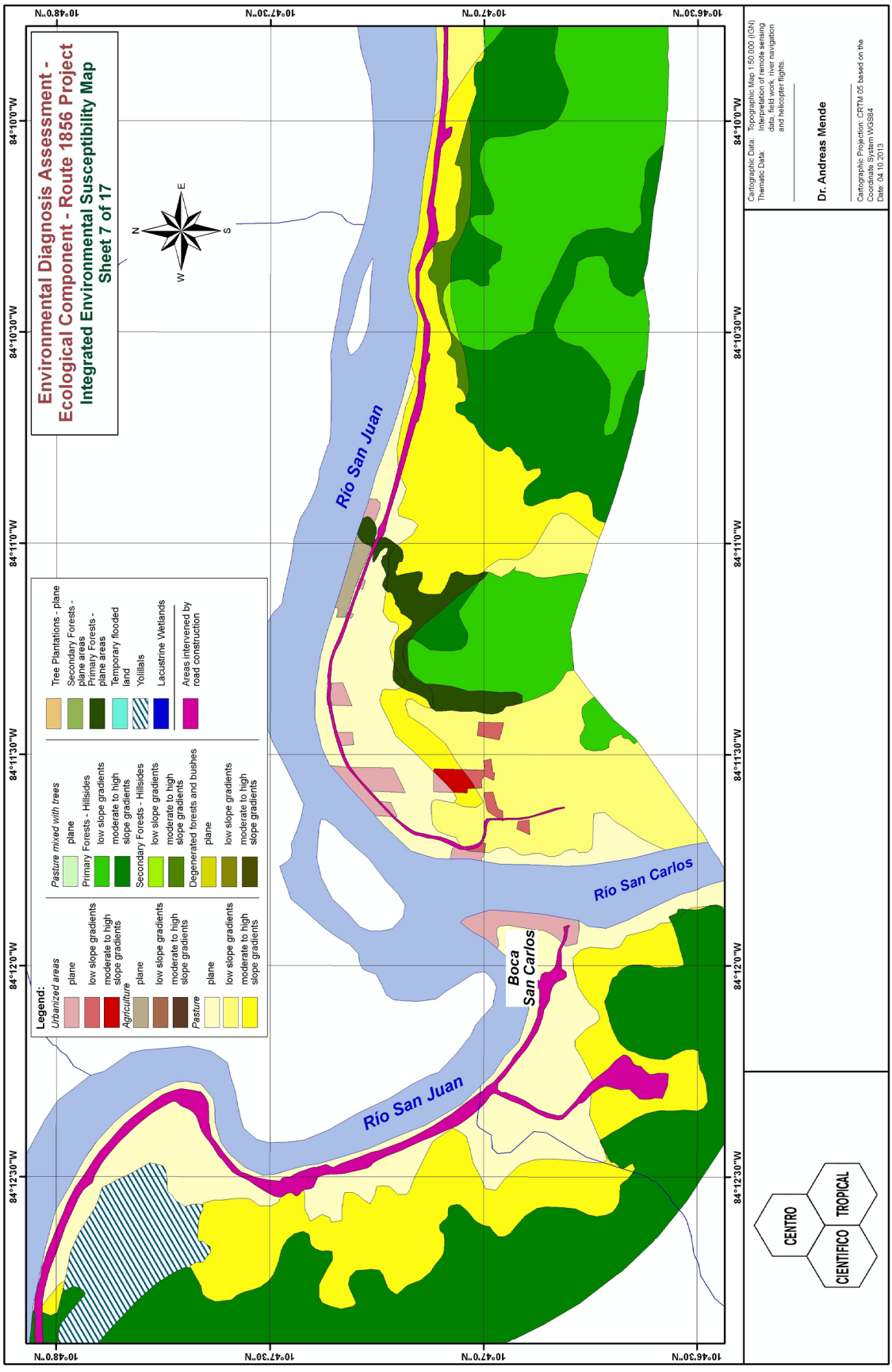

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 2 of 17
Tiricias
Rio San Juan
Rio Infiernillo
N
W
E
S
461500
462000
462500
463000
463500
464000
464500
1211000
1210500
1210000
1209500
1209000
1208500
1208000
1207500
1207000
1206500
1206000
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

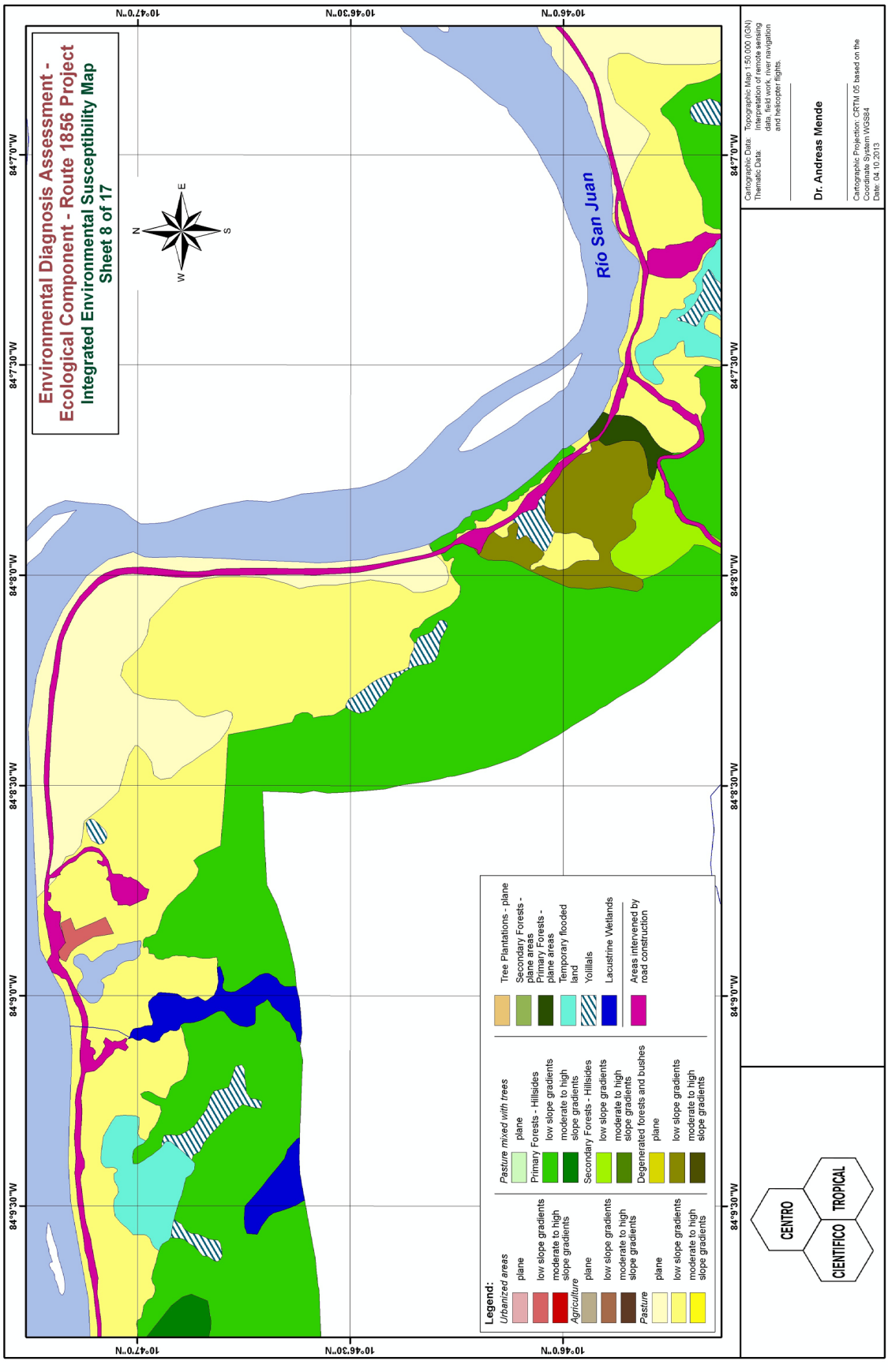

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 3 of 17
N
W
E
S
Río San Juan
Río Infiernillo
Crucitas
465000
465500
466000
466500
467000
467500
468000
1208500
1208000
1207500
1207000
1206500
1206000
1205500
1205000
1204500
1204000
1203500
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

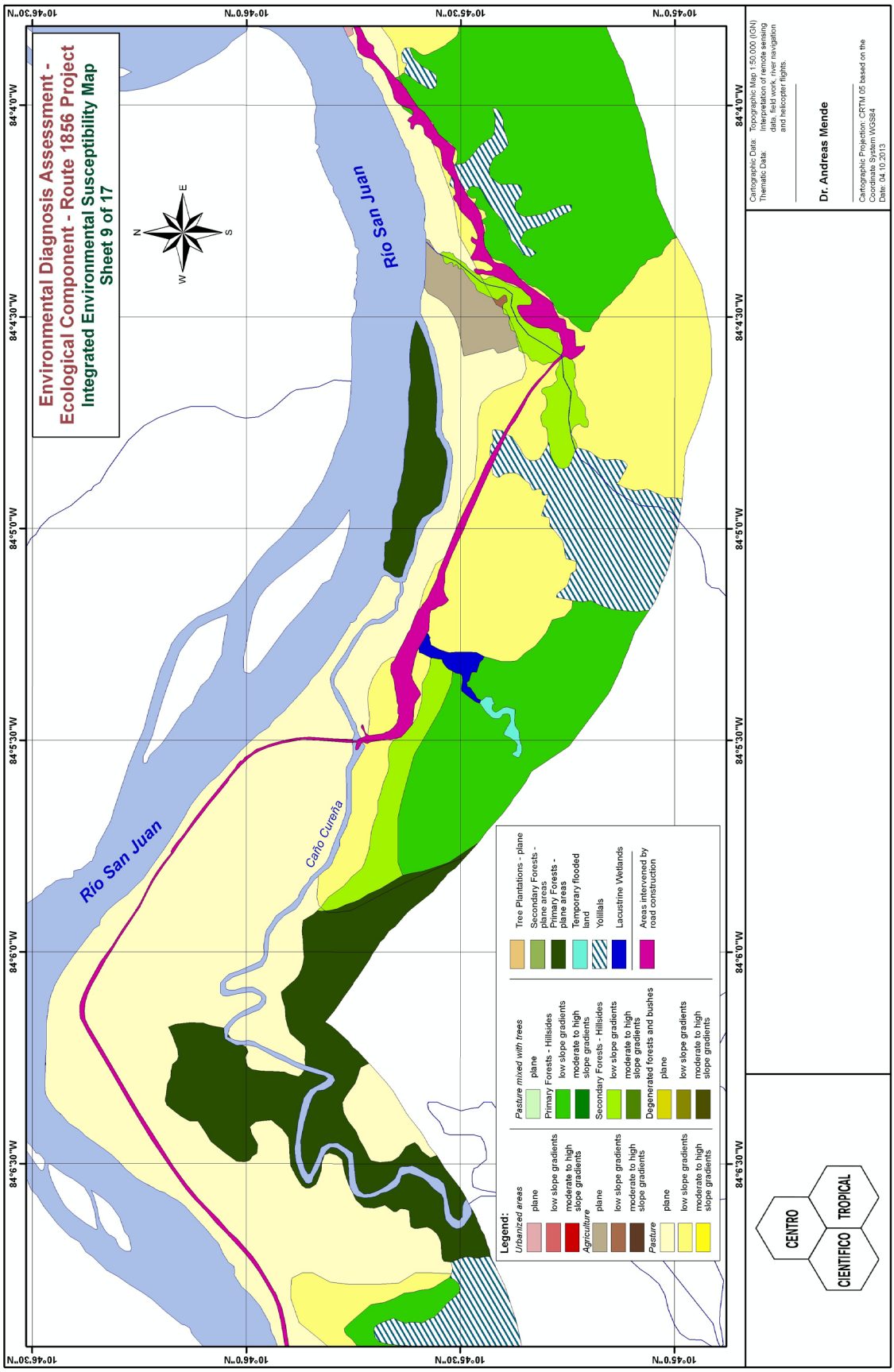

Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 4 of 17
Río San Juan
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO CIENTIFICO TROPICAL
84°17'0"W
84°16'30"W
84°16'0"W
84°15'30"W
84°15'0"W
84°14'30"W
10°54'0"N
10°53'30"N
10°53'0"N
10°52'30"N

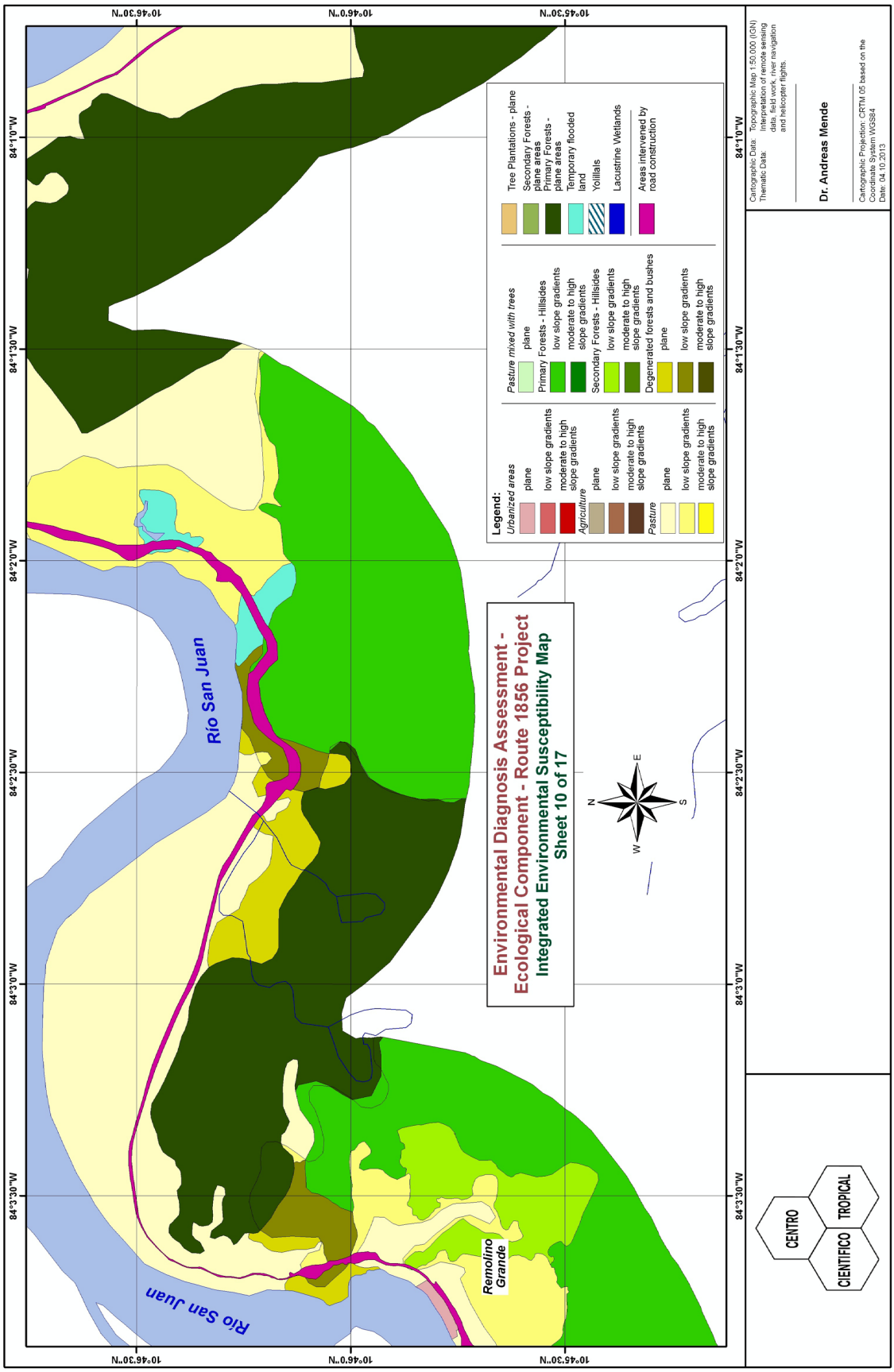

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 5 of 17
N
W
E
S
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
473500
474000
474500
475000
475500
476000
476500
1202500
1202000
1201500
1201000
1200500
1200000
1199500
1199000
1198500
1198000
1197500
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

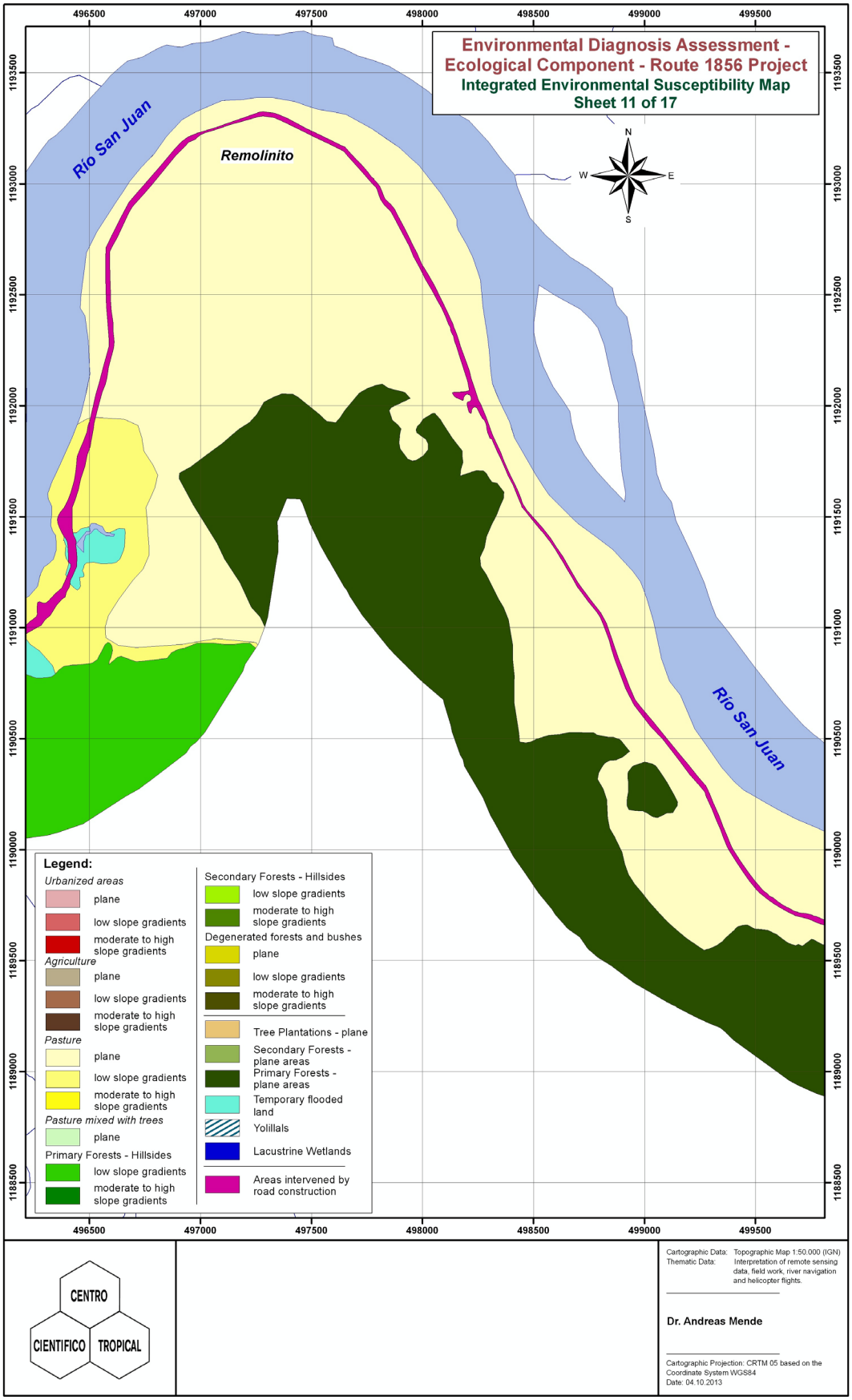

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 6 of 17
N
W
E
S
Río San Juan
El Jardín
473000
473500
474000
474500
475000
475500
476000
476500
1197500
1197000
1196500
1196000
1195500
1195000
1194500
1194000
1193500
1193000
1192500
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

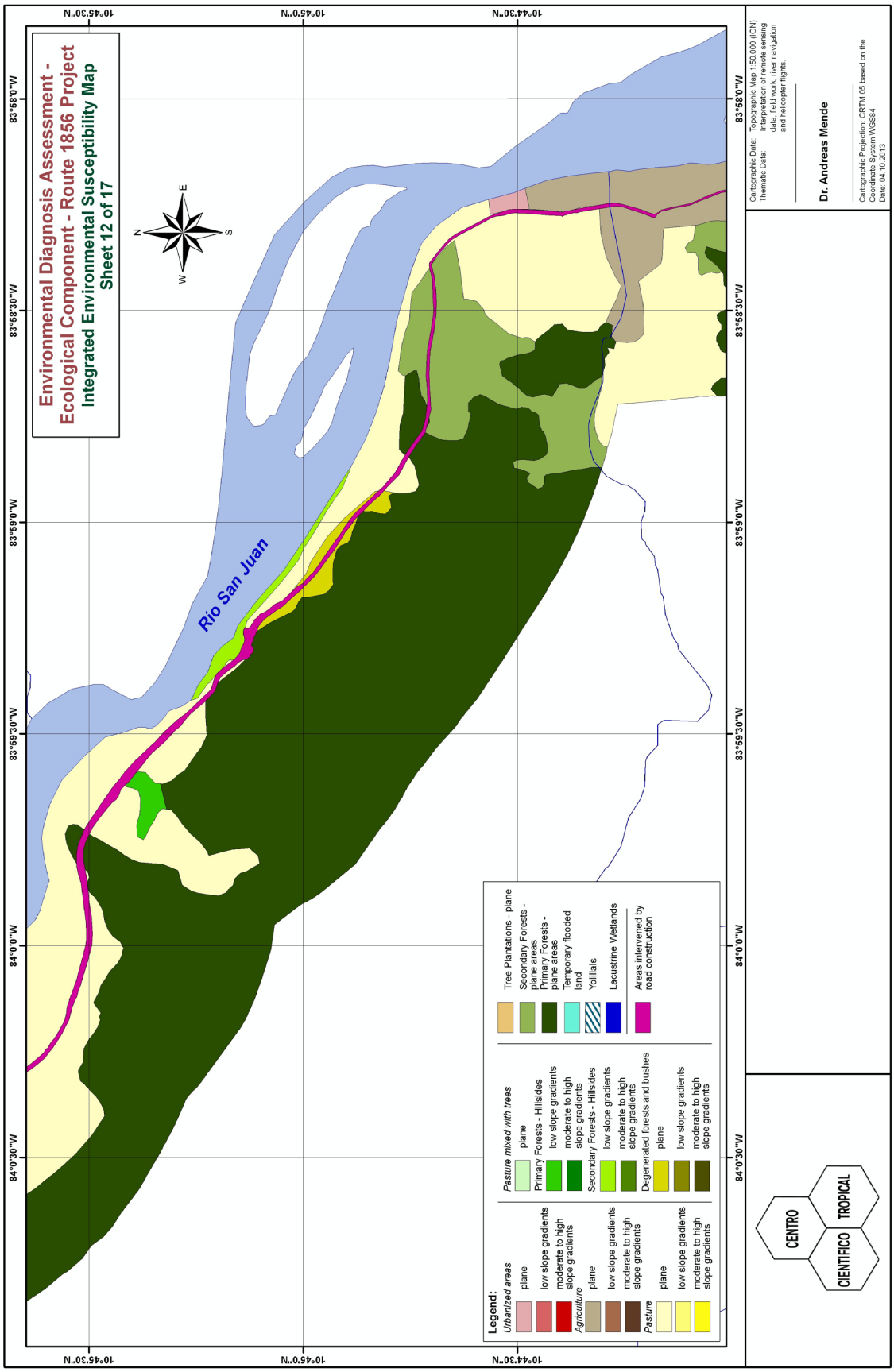

Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 7 of 17
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
Río San Juan
Río San Carlos
Boca San Carlos
Río San Juan
84°12'30"W
84°12'0"W
84°11'30"W
84°11'0"W
84°10'30"W
84°10'0"W
10°48'0"N
10°47'30"N
10°47'0"N
10°46'30"N
N
S
E
W
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO
TROPICAL
CIENTIFICO

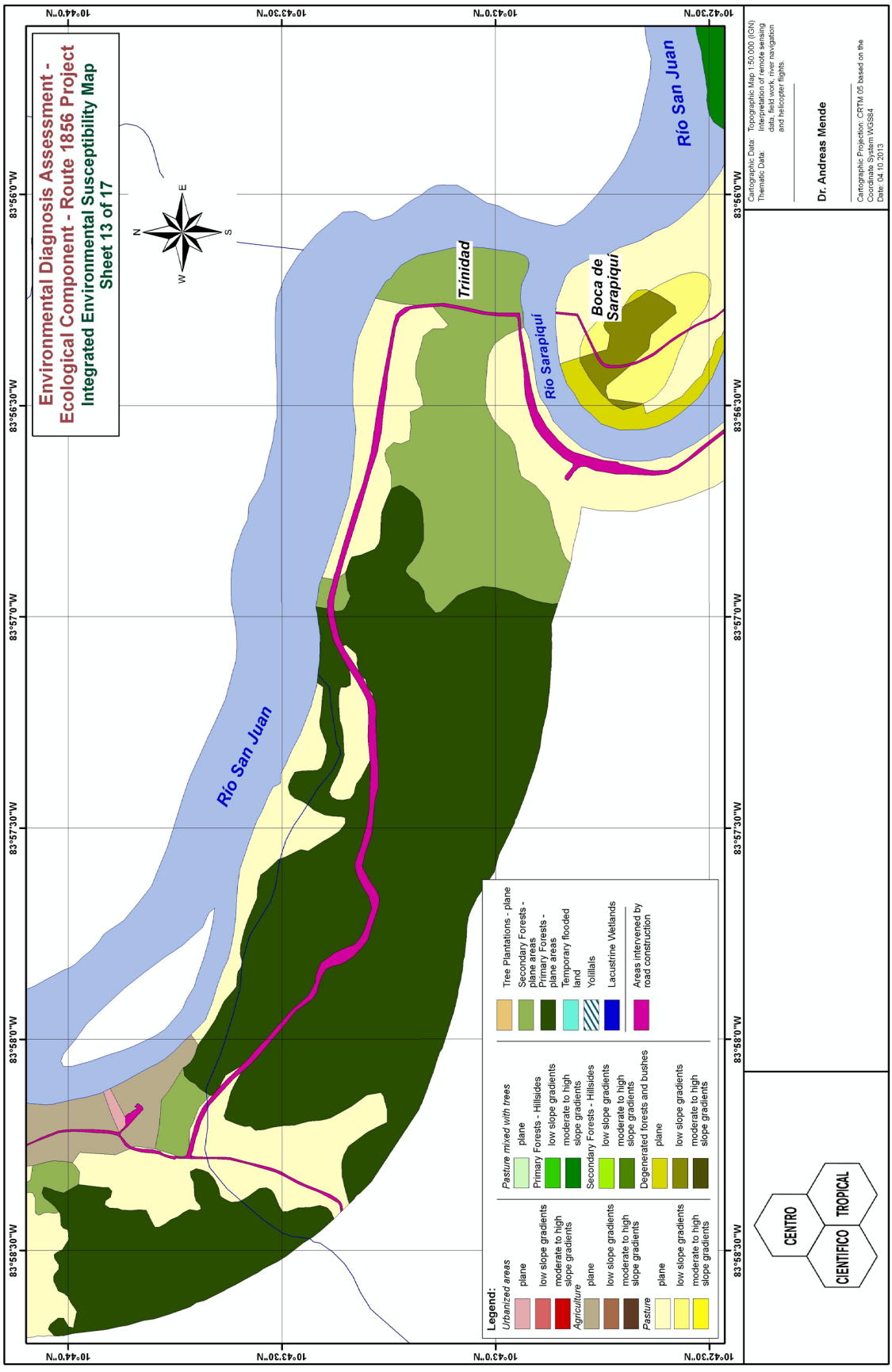

Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 8 of 17
Río San Juan
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
10°47'0"N
10°46'30"N
10°46'0"N
84°9'30"W
84°9'0"W
84°8'30"W
84°8'0"W
84°7'30"W
84°7'0"W

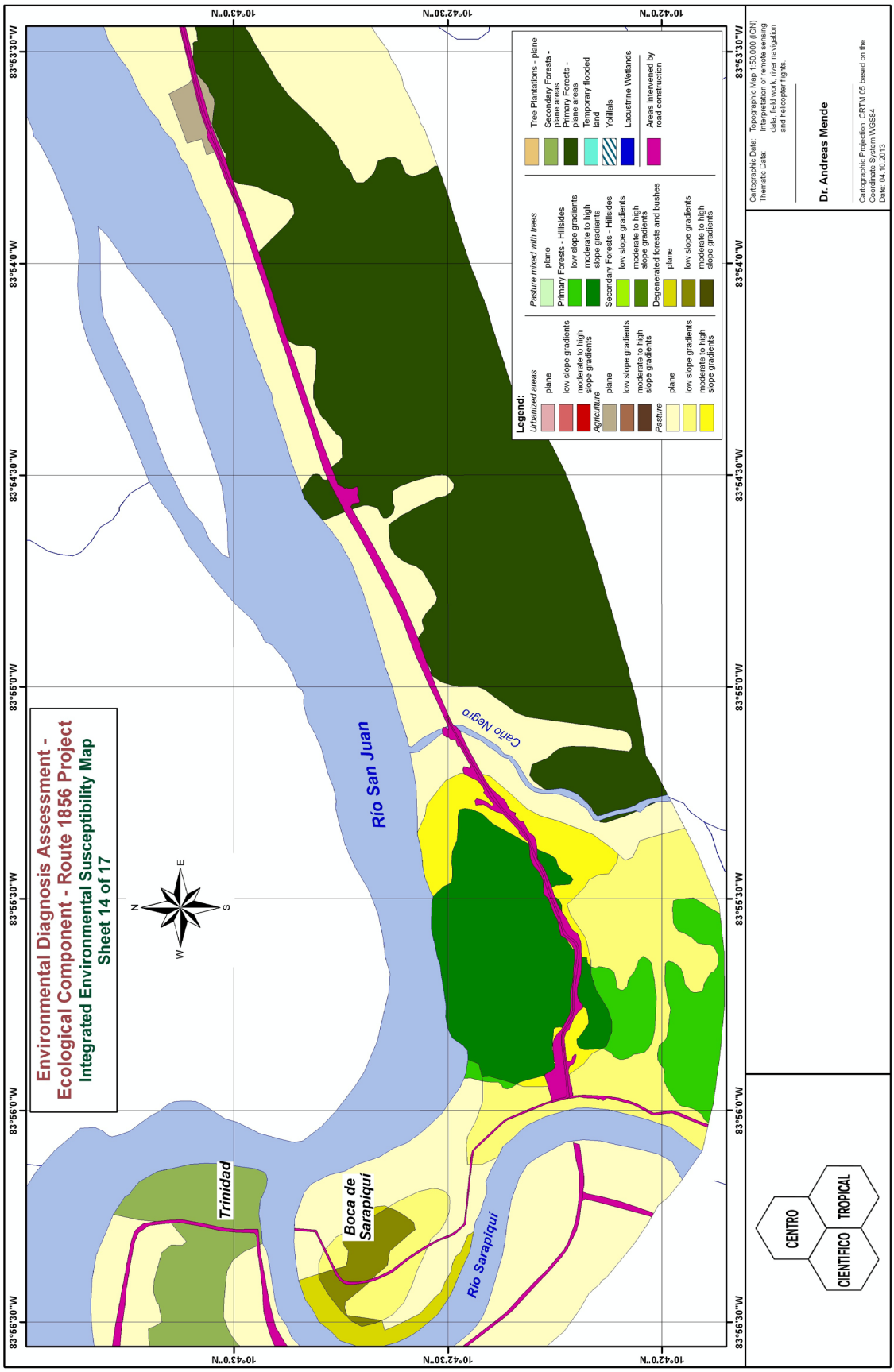

Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 9 of 17
Río San Juan
Río San Juan
Caño Cureña
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO CIENTIFICO TROPICAL

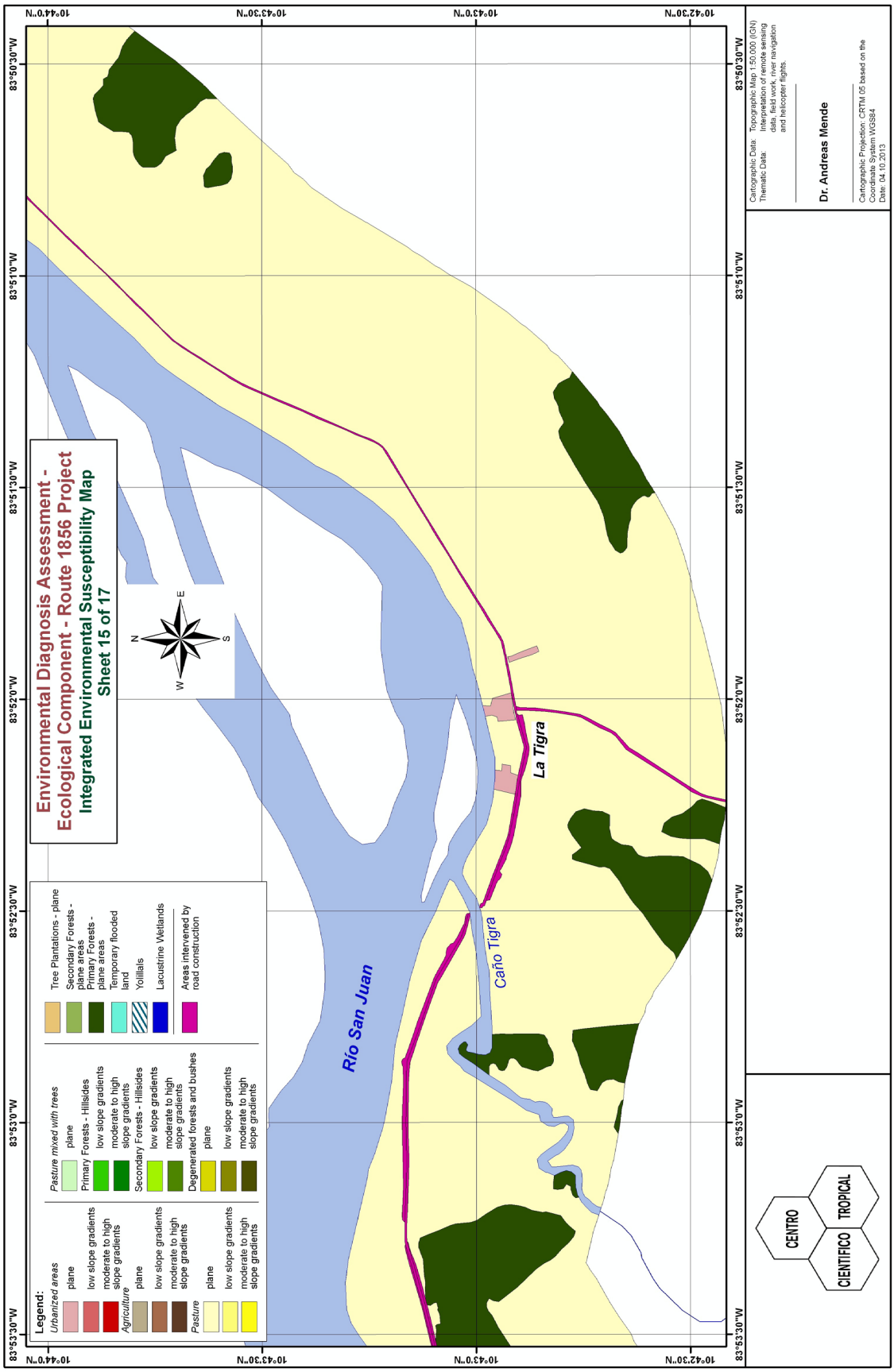

Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 10 of 17
Rio San Juan
Rio San Juan
Remolino Grande
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
84°3'30"W
84°2'30"W
84°1'30"W
84°0'30"W
10°46'30"N
10°46'0"N
10°45'30"N
N
S
E
W
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

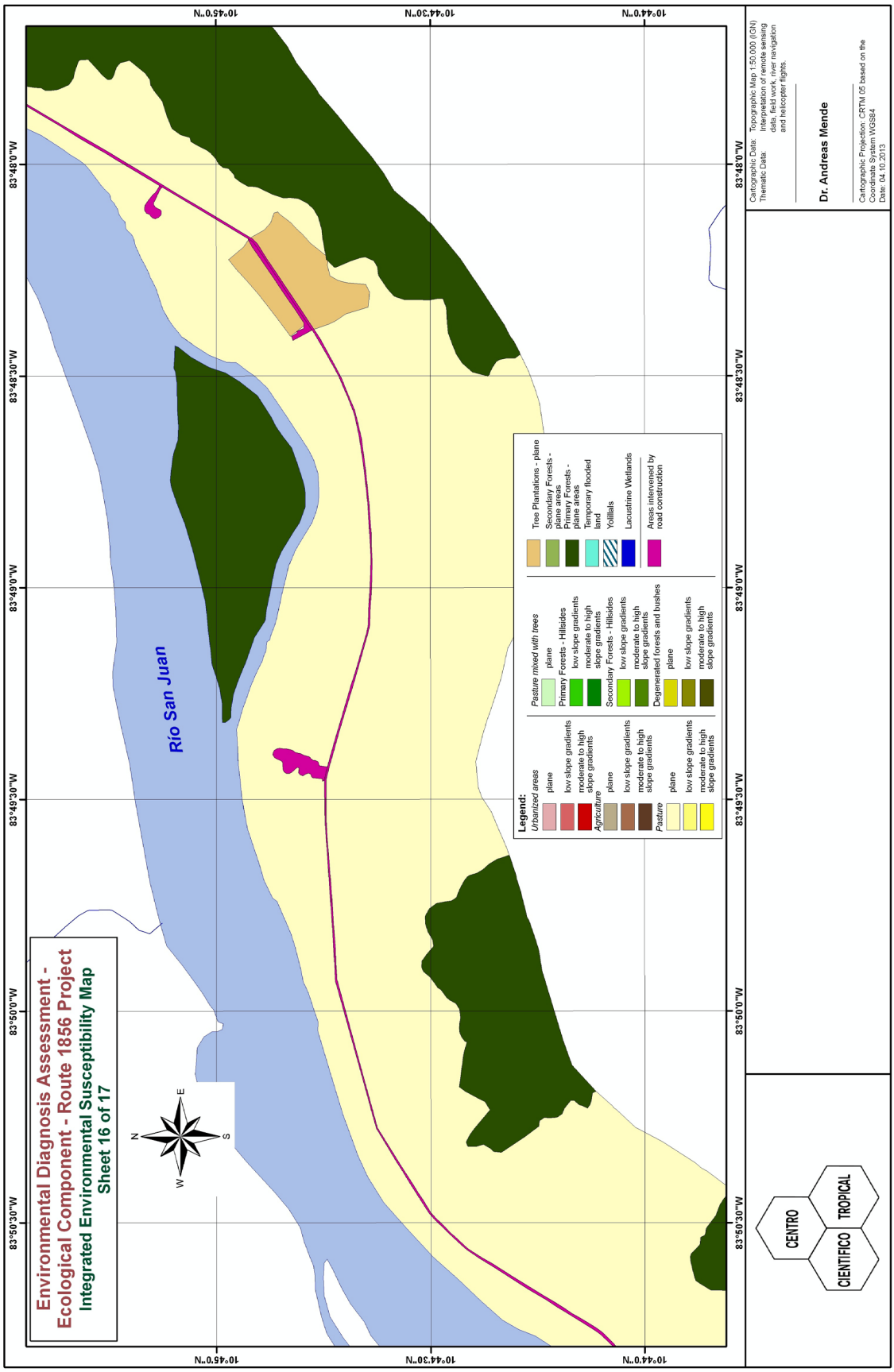

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 11 of 17
Río San Juan
Remolinito
Río San Juan
N
W
E
S
496500
497000
497500
498000
498500
499000
499500
1193500
1193000
1192500
1192000
1191500
1191000
1190500
1190000
1189500
1189000
1188500
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

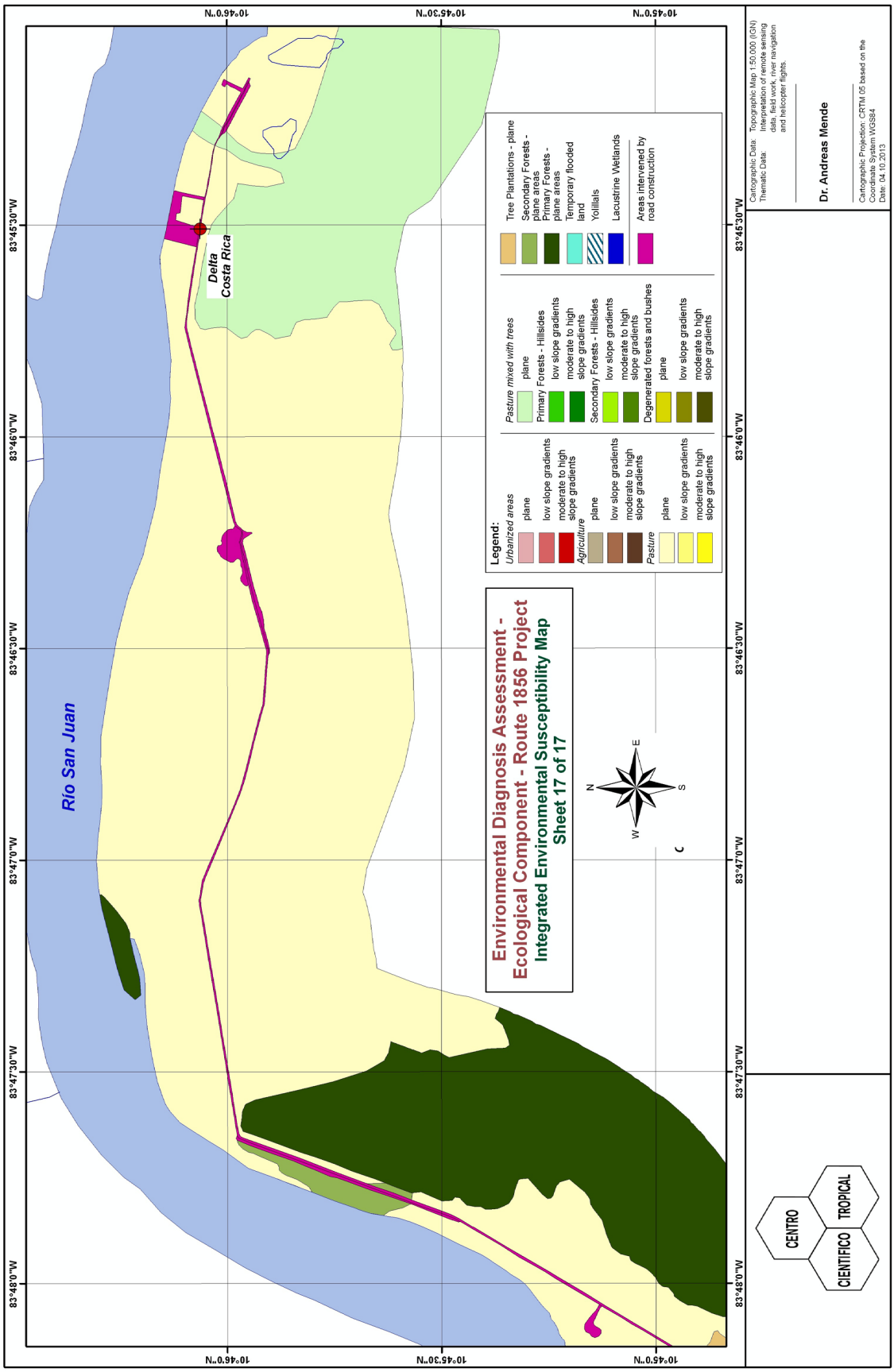

Environmental Diagnosis Assessment - Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 12 of 17
Río San Juan
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO CIENTIFICO TROPICAL
10°45'30"N
10°45'0"N
10°44'30"N
83°58'0"W
83°58'30"W
83°59'0"W
83°59'30"W
84°0'0"W
84°0'30"W
N
S
E
W


Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 13 of 17
Río San Juan
Río Sarapiquí
Trinidad
Boca de Sarapiquí
Río San Juan
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
CENTRO CIENTIFICO TROPICAL
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 14 of 17
Río San Juan
Caño Negro
Trinidad
Boca de Sarapiquí
Río Sarapiquí
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013
CENTRO CIENTIFICO TROPICAL
10°43'0"N
10°42'30"N
10°42'0"N
83°56'30"W
83°56'0"W
83°55'30"W
83°55'0"W
83°54'30"W
83°54'0"W
83°53'30"W


Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 15 of 17
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
Río San Juan
Caño Tigra
La Tigra
N
S
E
W
83°53'30"W
83°53'0"W
83°52'30"W
83°52'0"W
83°51'30"W
83°51'0"W
83°50'30"W
10°44'0"N
10°43'30"N
10°43'0"N
10°42'30"N
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50.000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 16 of 17
Río San Juan
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yollkals
Lacustrine Wetlands
Areas intervened by road construction
N
S
E
W
83°50'0"W
83°49'30"W
83°49'0"W
83°48'30"W
83°48'0"W
10°45'0"N
10°44'30"N
10°44'0"N
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013


Río San Juan
Delta
Costa Rica
Environmental Diagnosis Assessment -
Ecological Component - Route 1856 Project
Integrated Environmental Susceptibility Map
Sheet 17 of 17
Legend:
Urbanized areas
plane
low slope gradients
moderate to high slope gradients
Agriculture
plane
low slope gradients
moderate to high slope gradients
Pasture
plane
low slope gradients
moderate to high slope gradients
Pasture mixed with trees
plane
Primary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Secondary Forests - Hillsides
low slope gradients
moderate to high slope gradients
Degenerated forests and bushes
plane
low slope gradients
moderate to high slope gradients
Tree Plantations - plane
Secondary Forests - plane areas
Primary Forests - plane areas
Temporary flooded land
Yolillals
Lacustrine Wetlands
Areas intervened by road construction
N
E
S
W
83°48'0"W
83°47'30"W
83°47'0"W
83°46'30"W
83°46'0"W
83°45'30"W
10°46'0"N
10°45'30"N
10°45'0"N
CENTRO
CIENTIFICO
TROPICAL
Cartographic Data: Topographic Map 1:50,000 (IGN)
Thematic Data: Interpretation of remote sensing data, field work, river navigation and helicopter flights.
Dr. Andreas Mende
Cartographic Projection: CRTM 05 based on the Coordinate System WGS84
Date: 04.10.2013

6.2 Identification of impacts and environmental risks

This chapter, in accordance with the guide established through Resolution No. 2572-09 SETENA, identifies and describes the impacts, starting with two basic criteria. The first one refers exclusively to the reality analyzed and the conditions existing along the study area, which corresponds to the 108,2 km of Route 1856 from Border Marker 2 to Delta Costa Rica, a topic that was discussed in Chapter 5, specifically in the section related to the description of the biological environment.

The second criterion has to do with the evaluation of the impacts itself, and for which purpose the Matrix on the Importance of the Environmental Impact (MIIA) was applied, as officially approved by the SETENA for this technical aspect of the study. The identification as well as the evaluation of environmental impacts was conducted focusing only on those effects that are thought to require environmental control measures or actions.

6.2.1 Activities susceptible of causingenvironmental impacts

As indicated in Chapter 3, the different activities performed for the construction of the Route, are related to the appearance of some environmental impacts. The main activities that were identified in the Project were:

1. Clearing of land and brush in some sites located along the Route.
2. Earth movements, formation of slopes and landfills
3. Implementation of erosion control measures
4. Installation of drainage systems and temporal bridges
5. Installation of landfills, road base layers and rolling surface.

It should be pointed out that activities 1 and 2 were performed in specific sites of the Project and not as a continuous actions along the Route, and this is due to the fact that most of the terrain where the Route is located is flat or plain topography.

6.2.2 Impacted or potentially impacted environmental factors

According to what has been discussed previously, there are environmental factors that could be affected to a minor or major degree by the development of the road works. These factors are:

1. Surface waters
2. Soils
3. Natural threats (erosion, landslides)
4. Flora and Fauna (terrestrial and aquatic)
5. Landscape

6.2.3 Identificationof environmental impacts

Taking into account the environmental characteristics present along the route of the road, and the activities that are capable of generating an impact on the environment, as well as those factors that could potentially be impacted, a Leopold Matrix was formulated with some

modifications accounting for conditions and characteristics of the road project. The matrix offers quantitative identification of the potential impacts related to the works (see Chart 21).

In this matrix environmental factors that are susceptible to impact are identified (vertical column),as well as the components or activities of the Project that can generate impacts (horizontal row).

When the activity is significant, it is identified with an **A**, indicating the need to evaluate and establish specific measures. Furthermore three categories apply: Low (**X**), Moderate (**XX**) and High (**XXX**). When the activity is identified with a **B**, this indicates that its analysis is not relevant. It is necessary to indicate that only moderate and high impacts were analyzed in detail.

In the case of the factor "flora and fauna", these are separated for better understanding and evaluation into terrestrial and aquatic flora and fauna. It is important to note that some of these factors have similar characteristics, and for that reason they have been grouped in order to present a logical and sequential order.

Chart21: Modified matriz for impact identification related to Route 1856.

Factor		**Components**				
		Clearing and deforestation in some sites along the right of way	Soil movements, cutting of slopes and creation of landfills	Implementation of erosion control measures	Installation of drainage systems and temporal bridges	Installation of landfills, sub-base and rolling road surfaces
Biological Resource	Terrestrial flora – fauna	**A** (XX)	**A** (X)	**A** (X)	**B**	**B**
	Aquatic flora-fauna	**A** (XX)	**A** (XX)	**B**	**A** (XX)	**A** (XX)
	Landscape	**A** (XX)	**A** (XX)	**B**	**B**	**B**

6.2.4 Description of identified Environmental impacts

The following is an analysis of the environmental impacts identified or which could be generated by the Project. These are described according to the environmental factor affected.

6.2.4.1 Terrestrial flora and fauna

a. Logging in the right of way and adjacent areas

According to the evaluation of the plant cover along the length of the Project, it was estimated that, for purposes of clearing the land on the designated route of the road, 14,9 hectares of secondary forest were cut down along with 68,3 hectares of altered primary forest, which corresponds to 4,2% and 19,5% respectively of the area affected by the road design.

In complement, some 2,3 hectares were altered that were not forests but natural wetland systems. It was determined in the field that the opening of the route was executed mostly in

open areas without forest (74%). In cases where forests were cut down, it was due to the fact that there were no open areas where the path of the route could be directed.

b. Partial sedimentation of wetland margins near Route 1856

During the field work, it was observed that in the majority of wetland places along the Route, no areas are observable that are affected by sedimentation, since most of them are located on plains or flat terrain, where no significant earth movements occurred, except where filling was done on the road surface.

However, it was determined that at two wetland sites that are located next to hilly terrain, some sedimentation accumulation was observed, leading to a slight obstruction of sites close to the path of the natural drainage system of these wetlands. Even though no loss of tree or palm vegetation was observed it is possible that this loss is affecting ecosystems close to the road, with some natural substitution or alteration taking place of the original vegetation.

In complement, the lacustrine wetland Remolinito Grande has been affected by the filling of the road segment, even though there had been alteration occurring years ago, prior to the Route construction, substituting the aquatic vegetation with pasture and building a drainage system to allow for the wetland to be used for cattle grazing. These punctual impacts are located in the section between mouth of San Carlos and the mouth of the Sarapiqui rivers.

c. Elimination of trees and bushes on river margins due to flooding

It was determined that in the section between Border Marker 2 and the Infiernito River there are some sites with small streams that showed at the time of visit (during the rainy season) an accumulation of water, forming small pools of water on the plant vegetation along the side of the stream. This was due to the fact that gutters or drainage tubes collapsed, causing the flooding of ecosystems in the area estimated at 100 to 200 meters per site. This flooding led to the loss of vegetation.

d. Landslides and slope erosion that affects the forest margin along the route

In the sites of several land cuts where the road passes, and where there is forest vegetation on the margins of the cut, erosion layers of the ground of such cuts was observed, which generally causes the small trees (also two large trees were observed) to be uprooted due to the displacement of soil in their radicular system, causing them to fall on the road.

In similar form, but with lesser alteration, it was found that at several sites with steep slopes, landslides have occurred off the slopes on the sides of the road, carrying with them the edges of the slopes, including some small and large trees that fell and obstructed the road. Field observations led to the determination that this is accentuated by the surface runoff which takes place above the slopes.

This phenomena occur generally at the sites with steeper slopes, which are also often covered by forest, causing damage to the vegetation on slopes that run down past the Route. This impact is punctually located mostly between the sector close to the Infiernillo River and the sector known as Chorreras. This alteration has been occurring after the aperture of the Route and will probably continue to happen, as generally happens in these types of topographic settings and with soils that are susceptible to erosion.

e. Alteration of the wetland ecosystem (due to drainage and landfills)

This alteration corresponds with the alterations caused on wetlands by drainage and construction of artificial land fills in small areas along the path of the Route. This impact is very specific, located in defined points along the Route.

In the case of Yolillo palm patches, these present a loss of 0,7 hectares of the ecosystem due to drainage, burning or the construction of artificial landfills. The "Yolillal" is difficult to recover through reforestation and the only alternative is natural regeneration. In terms of landscape, the impact is minimal when the extension of the influence area of the Route is taken into account.

f. Impact on structural connectivity

This corresponds to the loss of structural connectivity as a result of the cutting down of forest cover in forests along some sections of the Project.

The identification of connectivity routes and the important connectivity areas along the landscape of the study area, it becomes clear that such are not related to the route traced for the road, despite the fact that the Route is located in the area of greatest forest cover in the study area. Given the reduced extension of natural ecosystems impacted (83,2 hectares), it is possible to say that the Route has not generated a significant impact on the structural connectivity of the landscape under study.

6.2.4.2 Aquatic flora y fauna

g. Potential alteration of the aquatic habitat

Possible alterations of the aquatic habitat are due to the drainage system and the laying of cement structures where gutters and drains are located. It could affect some of the aquatic organisms, since it produces homogenization of the substratum at a local level in sites where the Route cuts across the bodies of water, affecting the re-colonization of the aquatic ecosystem by macro-invertebrates because these organisms prefer heterogeneous substrata (Williams and Felmate 1992).

h. Potential alteration of the micro-habitats and substrata of the aquatic macro-invertebrates due to filling of interstices with sediments

Sedimentary material in the water and the decrease in the contribution of vegetal matter to the aquatic means, along with decrease in shade, cause the filling in of cavities and modify the substratum where aquatic macro-invertebrates normally live.

i. Potential alteration of taxonomic abundance and richness

Similarly to the previous impact, taxonomic richness could be diminished by sediments in the water, a decrease in vegetal matter in the aquatic environment, and the loss of shade.

j. Potential alteration of the quality of water due to turbidity

The contribution of sediments on the stream of water could affect the water quality due to the turbidity, or cloudiness, in some rivers, due to the construction works of the Route.

6.2.4.3 Landscape

k. Landscape Alteration due to the Route

The exposed surfaces of slopes and road cuts at some specific sites along the tracing of the Route, contrasts with the forest, pastures and dominant farming field landscapes. These visible points are located mainly along Border Marker 2 and the vicinity of the mouth of the San Carlos River.

6.3 Assessment of Environmental impacts and corective measures

6.3.1 Methodology

The assessment of environmental impacts that follows is based on the previous analysis and in correspondence with the methodology applied.

Starting with the characteristics established in the preceding chapters and sections, referring to the Project, as well as environmental conditions and the integrated analysis of such variables, each one of the participating professionals offered his/her technical criteria as related to an expected impacts, taking as criteria the guidelines offered by the Conceptual Guide for the Formulation of Environmental Impact Studies that the Secretaría Técnica Nacional Ambiental (SETENA) has recommended since 1998 and the modifications to this document found in Executive Decree No. 32967 of May 4, 2006: Technical Instruments Guide for Environmental Impact (EIA Manual) Part IV, Annex 2: Instructions for the Assessment of Environmental Impacts).

In this sense, conceptual definitions are reconsidered which will facilitate the final understanding of the Matrix of Importance of Environmental Impacts (MIIA), which summarizes the analysis of the expected impact of the project on the environment.

i. **Impacted Environmental Factor:** this denomination includes factors or elements of the environment (ecological component) that may be affected by the development of the project or by any of its actions. The elements that have been selected for environmental evaluation are those that are considered to be potentially related to Project activities.

ii. **Action that Causes an Impact:** definition at a detailed level is offered of the act, activity or component of the Project that exerts an impact on one or several of the environmental factors defined in the previous point. The impacting act may be related to the construction or operative phase of the Project.

iii. **Impact:** Indicates the effect expected in each of the impact possibilities identified by the members of the study team. If the expected impact is the contamination of water, the cause of impact is identified, along with the source of contamination and the phase of the Project where the potential impact may occur.

iv. **Impact Assessment:** correspond to the quantitative grade given to the environmental impact, the evaluation is based on the criteria offered by the Leopold Matrix (modified) and which have been discussed for some time in Costa Rica, where they have been adapted to the Matrix of Importance of Environmental Impacts (MIIA) by SETENA and made official by Executive Decree No. 32966 –MINAE (Technical Instruments Guide for the Process of Environmental Impact Assessment (EIA Manual)-Part IV).

Criteria to be evaluated correspond to those in Chart 22.

Chart22: Evaluation criteria for the MIIA.

Evaluation Element	Description	Value Range
Sign	The sign referring to effect and thus to impact, refers to the *beneficial* (+) or *negative* (-) character of the different actions that affect the different factors under consideration	*Beneficial*(+) *Negative*(-) Undetermined (*)
Intensity (IN) Degree of Incidence	Degree of incidence of the action on the factor, in the specific context. The scale ranges from 1 to 12, where 12 is the maximum destruction of the factor (AP_{total}) and 1 is the minimal impact value. This evaluation is a function of the percentage of the Project area (PA and/or influence areas where applicable) that is being directly affected.	Low: 1 Medium: 2 High: 3 Very high: 4 Total: 12
Extensión (EX) Influence Area	This is the theoretical influence area of impact in relation to the environment of the activity (percentage of the area, with respect to the context in which the effect is present). In Costa Rica it will be used as reference for quantification of the Direct Influence Area (DIA). If the action produces a localized effect, the impact will be considered to have a punctual effect (1). If, on the other hand, the effect does not permit a precise localization within the context of the activity, having instead a generalized influence in all of it, the impact will be considered to be total (8), taking intermediate areas, according to their degree, to be partial (2) and extended (4) In case the impact occurs in a critical location (spill near and upstream from a water source, landscape degradation in an area of high visitation or near an urban center, etc.) will receive a grade of 4 units above that which would correspond as a function of the percentage of the extension of its presence.	Punctual: 1 Partial: 2 Extended: 3 Total: 4 Critical: (+4)
Momentum (MO)	The moment of impact is the period during which the impact occurs from the initiation of the action (t_o) and the beginning of the impact (t_j) on the factor/environmental aspect being consired. When the time period elapsed is null, the moment will be immediate, and if it is inferior to a year, it will be considered short term, assigning both a value of (4). If it is a time period that ranges from 1 to 5 years, it will be considered medium range, and if the impact takes longer than 5 years to manifest itself, it will be considered long term, with an assigned value of (1). If a circumstance appears that makes the impact moment critical it would receive a value of (4) units above those specified.	Long term: 1 Medium term: 2 Immediate: 4 Critical: (+4)
Persistence (PE)	This refers to the time of permanence of the effect from its initial appearance and the point at which the impacted factor World return to the initial conditions prior to the impact, base on natural processes or the introduction of	Passing: 1 Temporal: 2 Permanent: 4

Evaluation Element	Description	Value Range
	corrective measures. If the permanence of an impact has place during a time period of less than a year, the impact is considered to have a passing effect, with a value of (1). If it lasts between 1 and 5 years, it is considered temporal (2); if the impact has a duration over 5 years, it is considered to be permanent, receiving a value of (4).	
Reversibility (RV)	This value refers to the possibility of reconstructing the impacted factor as a consequence of the actions taken, that is, the possibility of returning to initial conditions present before the impact through natural means once the impacting action ceases to impact the environment. If it is short term, that is to say less than 1 year, it is assigned a value of (1), and if medium term, a 1 to 5 years period, it is assigned a value of (2), and if the impact is irreversible or lasts more than 5 years, it is assigned a value of (4). Intervals that comprehend these periods are identical to those assigned in the previous parameter.	Passing: 1 Temporal: 2 Permanent: 4
Recovery (MC)	This refers to the possibility of total or partial reconstruction of the impacted factor as a consequence of the activity in question, that is to say, the possibility of returning to initial conditions present prior to the impact, through human intervention (introduction of corrective measures). If the impact permits total recovery, and if recovery is immediate, it receives a value of (1), or a value of (2) if recovery is at medium range; and if recovery is partial and the impact can be mitigated, the value assigned is (4). When the impact is not capable of recovery (impossible to repair either by natural or human action) the value assigned is (8).	Immediate Recovery: 1 Medium Term Recovery: 2 Partial Recovery and Mitigation Possible: 4 Recovery Impossible: 8
Sinergy (SI)	This attribute considers the reinforcement of two or more simple effects. The total component of the manifestation of simple effects, provoked by actions that act simultaneously, is superior to what could be expected from manifestation of actions that act independently and not simultaneously (the lethal dose of a product A, is the DLA and the dose of product B is DLB. Applied simultaneously, the dose of both products DLAB is greater than DLA and DLB). When an action that impacts on a factor is not synergic with other actions that act on the same factor, the value assigned is (1), and if synergy is moderate, the value is (2). It there is high synergy, the value is (4).	No synergy: 1 Moderate Synergy: 2 Very Synergic: 4
Accumulation (AC)	This characteristic is based on the idea of the progressive and cumulative effect of the impact, when the action that generates it is persistent or continuous. When an action does not produce cumulative effects (simple accumulation), the effect is assigned a value of (1).	Simple: 1 Cumulative: 4

Evaluation Element	Description	Value Range
	If the effect is cumulative, the value assigned is (4).	
Effect (EF)	This feature refers to the cause-effect relationship in terms of direction, that is to say the manner in which the effect manifests itself on a factor as a consequence of an action. The effect may be direct or primary, in which case the impact is a direct consequence of the action, with a value assigned of (4). In case an indirect or secondary effect is present, that is to say, the effect is a result of a primary effect and no direct effect exists associated to that action, the impact value assigned is (1). Its manifestation is not a direct consequence of the action, but it is the result of a primary effect, acting as a secondary order.	Indirect (secondary): 1 Direct: 4
Periodicity (PR)	This refers to the regular manifestation of the effect, whether cyclic or recurrent (periodic effect), sporadic in time (irregular effect), or constant over time (continuous). Continuous effects are assigned a value of (4), while periodic effects receive a value of (2) and those of irregular manifestation, which must be evaluated in terms of probability of occurrence, as well as discontinuous over time, receive a value of (1). An example of continuous effects is the occupation of a space due to construction of a building.	Irregular, sporadic and dis-continuous: 1 Periodic: 2 Continuous: 4

Source: Manual de Instrumentos Técnicos para el Proceso de Evaluación de Impacto Ambiental (Manual de EIA)-Parte IV-SETENA).

According to what is established in Decree No. 32967, the importance of the impact or effect of an action over an environmental factor is represented by a number that is obtained through the proposed model, as a function of the value assigned to the previously discussed symbols:

$$I = \pm [IN + 2\,EX + MO + PE + PV + SI + AC + EF + PR + MC]$$

The importance of the impact is assigned values between 13 and 100 according to the expected impact on each element or factor, and presentes intermediate values (betwee 40 and 60), when some of the following circumstances apply:

- Total Intensity, and minimal impact on the remaining symbols
- High or very high intensity, and high or very high effect in the remaining symbols
- High intensity, no recovery effect and very high impact on some of the remaining symbols.
- Medium or low intensity, no recovery, and very high impact in at least two of the remaining symbols.

Therefore, the importance of the impacts is provided by the following values :

- Importance of impacts inferior to **25**, makes them irrelevant.
- Importance between **25** and **50**, means moderate impacts.
- Importance between **50** and **75** means severe impacts.

- Importance greater to **75** is a critical level of impact.

In those squares that correspond to the more important impacts, or when occuring in critical moments or places and are not subject to recovery, which will lead to the higher scores in the chart related to importance, the Alert of Red Flags are superimposed, in order to call attention to the effect and search for other alternatives in the activity´s productive process, work or project, to eliminate the cause or have it permutted to another activity with less harmful effects.

6.3.2 Impact Assessment

Starting with the negative impacts associated with the project, the criteria and parameters of evaluation are applied in each case. The prevously identified impacts will be the object of this evaluation. These are :

1. Deforestation along the right of way and contiguous areas.
2. Partial sedimentation of the edges of wetlands neighboring Route 1856.
3. Loss of trees and bushes located on the margins of streams due to flooding
4. Landslides and erosion of slopes that affect the forested margins of the road
5. Impact on the ecosystem of the wetlands (drainage of landfill)
6. Impact on the structural connectivity
7. Potential impact on aquatic habitat
8. Potential impact of micro-habitats and aquatic macro-invertebrate substrata due to filling of interstices with sediment
9. Possible decrease in taxonomic abundance and richness
10. Possible impact on the quality of waters due to turbidity caused by sediment.
11. Landscape impact due to the construction works.

Chart 23 corresponds to the Matrix of Importance of Environmental Impacts (MIIA) defined with the application of criteria established by the Manual of Technical Instruments for the Environmental Impact Evaluation Process (EIA Manual)- Part IV (SETENA, 2004) taking into account the importance of each according to their characteristics, environmental aspects and effects that are generated.

Chart 23: Matrix of Importance of Environmental Impacts (MIIA) for the Route 1856 project in Costa Rica territory.

Matrix of Importance of Environmental Impacts (MIIA) for the Route 1856 project in Costa Rica territory															
			Impact Characteristics												Assessment
			+/-	IN	EX	MO	PE	RV	SI	AC	EF	PR	MC	I	
No.	Environmental Factor	Impact													
1	Terrestrial Flora and Fauna	Deforestation along the right of way and contiguous areas	-	2	1	4	4	4	1	1	4	4	4	-34	Moderate
		Partial sedimentation of the edges of wetlands neighboring Route 1856	-	1	1	4	2	2	1	4	1	2	4	-25	Irrelevant
		Loss of trees and bushes located on the margins of streams due to flooding	-	1	1	2	2	2	1	1	1	2	2	-18	Irrelevant
		Landslides and erosion of slopes that affect the forested margins of the road	-	1	1	2	2	2	2	4	1	2	4	-24	Irrelevant
		Impact on the ecosystem of the wetlands (drainage of landfill)	-	1	1	4	2	2	1	1	4	1	4	-24	Irrelevant
		Impact on the structural connectivity	-	1	1	1	2	2	1	1	1	1	4	-18	Irrelevant
2	Aquatic Flora and Fauna	Impact on aquatic habitat	-	2	1	2	2	2	1	1	4	2	2	-24	Irrelevant
		Potential impact of micro-habitats and aquatic macro-invertebrate substrata due to filling of interstices with sediment	-	4	1	2	2	2	1	4	1	1	2	-29	Moderate
		Possible decrease in taxonomic abundance and richness	-	1	1	2	2	2	1	4	1	1	2	-20	Irrelevant
		Possible impact on the quality of waters due to turbidity caused by sediment	-	4	2	2	2	2	1	4	4	1	2	-34	Moderate
3	Landscape	Landscape impact due to the construction works	-	1	1	4	2	2	1	4	4	1	2	-25	Irrelevant
	Total	**Environmental impacts residual**												**-275**	

Note[1]: Modified from Decreto Ejecutivo Nº 32966-MINAE (Manual de Instrumentos Técnicos para el Proceso de Evaluación de Impacto Ambiental (Manual de EIA)- Parte IV) (SETENA, 2004).

Taking into account the results of the evaluations of Chart 23, it is determined that only 8 irrelevant impacts have been identified and 3 impacts of moderate type. Furthermore, these present very unique characteristics, among them:

1. None of the impacts is recurrent along Route 1856; these are located in very specific sites of the Project.
2. All impacts present a low to medium degree of intensity on the environment.
3. All impacts present a uniform evaluation between grades 20 to 34, which indicates a degree of homogeneity in the low incidence of impacts along Route 1856.

On the other hand, it is considered necessary to evaluate the conditions that were previously identified, from the perspective of potential impacts on Nicaraguan territory, where a similar analysis was done, of each of the potential activities that might generate an impact, in order to verify if the same could have manifestations on the San Juan River.

It is worth stating that it was not possible to carry out the previous suggestion since the Government of Nicaragua did not allow the scientists that conducted this study to enter Nicaraguan territory along the San Juan River in order to conduct sampling in the mouths of the different bodies of water that were analyzed. Chart 24 shows the results of the analysis of such evaluations.

Although it was not possible to prepare such a matrix based on field data taken at Nicaraguan territory, it is not considered there could be any significant impact on the San Juan river.

6.4 Risk analysis and contingency plans

6.4.1 Sources of environmental risk

According to the activities that were developed as part of the road construction, some sources of environmental risk were identified and mitigation measures implemented in order to avoid disturbance of terrestrial and aquatic environments:

1. Risk of cutting down trees that are threatened with extinction.
2. Risk of erosion and instability on slopes due to inappropriate drain design and lack of protection of the slopes.
3. Risk of alteration of natural drainage.
4. Risk of obstruction of waterways due to potential collapse and fall of trees, metal structures and construction aggregates that could create artificial obstruction of such.
5. Risk of sedimentation due to the Project construction works.

Chart 24: Matrix of Importance of Environmental Impacts (MIIA) for the Route 1856 project in Nicaragua territory

Matrix of Importance of Environmental Impacts (MIIA) for the Route 1856 project in Nicaragua territory															
			Impact Characteristics												Assessment
			+/-	IN	EX	MO	PE	RV	SI	AC	EF	PR	MC	I	
No.	Factor ambiental	Impacto													
1	Aquatic Flora and Fauna	Impact on aquatic habitat	-	-	-	-	-	-	-	-	-	-	-	0	-
		Potential impact of micro-habitats and aquatic macro-invertebrate substrata due to filling of interstices with sediment	-	-	-	-	-	-	-	-	-	-	-	0	-
		Possible decrease in taxonomic abundance and richness	-	-	-	-	-	-	-	-	-	-	-	0	-
		Possible impact on the quality of waters due to turbidity caused by sediment	-	-	-	-	-	-	-	-	-	-	-	0	-
2	Landscape	Landscape impact due to the construction works	-	-	-	-	-	-	-	-	-	-	-	0	-
	Total	**Environmental impacts residual**												**0**	

Note [1]: Modified from Decreto Ejecutivo Nº 32966-MINAE (Manual de Instrumentos Técnicos para el Proceso de Evaluación de Impacto Ambiental (Manual de EIA)- Parte IV) (SETENA, 2004).

Note [2]: It was not possible to conduct the impact analysis and assessment on the Nicaraguan territory due to prohibition by the Nicaragua Government for the Costa Rican scientific team to collect samples in the San Juan river at the river mouths of analyzed waterways.

6.4.2 Environmental risk evaluation

Chart 25 presents the evaluation for each of the risk sources identified, as well as the mitigation measures that should be incorporated in the Environmental Adequacy Plan. These will be classified as Low, Moderate and High, according to the value obtained.

Chart25: Environmental risk evaluation for the Route1856 project.

Risk Source	*Evaluation*	*Contingency Measure*
Cutting down threatened tree species	**Low**	• Inventory of trees along the right of way of Route 1856 • Monitoring the designated route of Route 1856.
Erosion and Instability of Slopes	**Low**	• Design of slopes that adjust to the topography and design of the road. • Preventiveinitiatives through the construction of civil works. • Monitoring of the path designated for the construction of Route 1856.
Alteration of natural drainage systems	**Low**	• Design of road adjusted to the drainage and rainfall characteristics. • Preventive actions through the construction of appropriate civil works. • Monitoring of the route designated for the road.
Obstruction of waterways	**Low**	• Monitoring of the state of structures along designed path of the Route 1856.
Alluvial Sedimentation	**Medium**	• Control of sedimentation processes in different bodies of water. • Monitoring along the path of Route 1856.

As presented in the previous chart and taking into account that the majority of risks identified along Route 1856 have been assessed as being low, it is generally determined that the risks studied are of an irrelevant character. In the case of alluvial sedimentation, several factors exist that alter the results of the evaluation due to the fact that there is a sedimentation behaviour in the rivers that is due to the fact that analyses were conducted during the rainy season. It is also necessary to point out that in the majority of the upper part of the watersheds analysed there are agricultural activities taking place that in some way affect the results obtained.

Nevertheless, that does not mean that the proposed measures should not be implemented, on the contrary. It is the responsibility of the CONAVI (National Transportation Commission) and institutions involved in the Project, to guarantee the mitigation of all the effects produced by the work, even though of a low and punctual character.

In the case of risk due to erosion and instability of slopes, and even though this is present only at specific points along the route, the degree of slope is a determinant aspect of the stability condition. That is the reason why they should been improved and mitigated for each specific case, taking into account first the degree of slope and, second, the composition of the geological materials *in situ*.

As a function of this assessment, the subject of risk has been objectively considered and for this reason it will be necessary at the same time to establish concrete actions as part of the Environmental Adequacy Plan (PAA).

6.5 Environmental control measures

Continuing with the guidelines established in Resolution No. 2572-2009-SETENA, environmental control measures refer to "all measures tending to prevent, attenuate or compensate the negative impacts of the activity, following such order of priority. Moreover, it includes the management and control of environmental risks. Such measures arise as a result of the evaluation of negative environmental impacts, as well as the risks evaluated in the EDA, and they are a basic component of the Environmental Adequacy Plan (PAA).

In the environmental evaluations of the previous chapters, a total of 11 punctual environmental impacts were identified, 8 of the type considered "irrelevant" and 3 of the moderate type, that were produced during the construction of Route 1856, and which, if not properly managed, could appear once again in the short run. An additional 5 sources of environmental risk were identified that require the establishment of mitigation measures.

6.5.1 Environmental control measures for the identified impacts

The following measures estimate preventive actions, in case the impact does occur, as mitigation or compensatory measures. All environmental measures will be cited in the Environmental Adequacy Plan (PAA).

The identified environmental impacts that the Project generated or that could be generated, will be analyzed later. These are described according to the environmental factor impacted.

6.5.1.1 Control measures for terrestrial flora and fauna

a. Partial deforestation along the right of way and adjacent areas

Source of impact/risk

Due the clearing of land and vegetation along the Project route, it was necessary to eliminate some trees along sections of the designated path of the route, specifically at sites where no previous roads existed.

The quantity of trees cut down was determined by the needs of each section of the route and the existing plant cover. This is so because along most of the designated route at least 74% of the way was in areas of open lands without plant cover. For that reason, in most sections where the Route was built, it was not necessary to eliminate forest cover. Nevertheless, it is necessary to

establish environmental measures to avoid deforestation along the Route path, in the medium and short range.

Environmental measures implemented

During the final months, a reforestation initiative has been developed with the planting of thousands of trees along both sides of the right of way of Route 1856, as mitigation measures proposed by the Ministry of the Environment, Energy and Telecommunications (MINAET). This plan has had an important process of growth and maintenance of the trees, involving local communities in the planting and protection activities.

Environmental measures to be implemented

1. To strengthen reforestation plans in existence with the planting of trees in areas where it is not necessary to cover road cuts, reforesting with scarce native species, threatened or endemic, avoiding exotic plants or species that are not present locally. It is recommended to mix species, simulating the forest diversity and that species include an approximate proportion of 50% of those common in the area, which are now decimated, such as the manú, cocobolo and jícaro. The other 50% should include species that are planted commonly in reforestation plans in the area. Priority areas should be sites with undulating slopes or strongly undulated and in the border strand along the San Juan River, and other rivers or creeks in the area of Route 1856.
2. To allow the natural regeneration of secondary vegetation where it appears aggressively, not cutting it down to plant trees, or making use of arboreal species as shade to favour species that are intolerant to the sun or which grow better in the shade in their early growth stages, such as the manú, pinillo or the almendro de montaña, for example. At sites with very slanted slopes it is advisable to allow secondary growth vegetation to re-establish itself, if possible. Given the fact that the total loss of natural forest cover was quantified at 83 hectares, it is suggested that an area similar to that deforested be allowed to recover its natural secondary vegetation, in a section lying next to the road, giving priority to hilly areas adjoining the San Juan River, as a way to compensate the native ecosystem, since commonly reforestation programs do not propitiate ecosystems such as those required to maintain native biodiversity. With the purpose of verifying the existence of tree species that are threatened within the right of way of the Route, it would be advisable to establish a forest inventory of forest species found along the Route.
3. To establish a protection and maintenance plan for trees identified.
4. To conduct periodic monitoring along the route design to avoid squatter incursions in the neighboring areas.
5. To promote the identification of different sections and ecosystems along the route as a tourism incentive.

b. Parcial sedimentation of wetland margins neighboring to Route 1856

Source of impact/risk

Soil movements, slope building and land fills generated slope instabilities on hillsides in some places where the degree of sloping is very high, as well as superficial runoff increase,

sedimentation along some nearby wetland margins; and the landscape disturbance along some sections of the Route 1856.

This impact corresponds with punctual alterations along the Route, where, in some adjacent sites, small quantities of sediment accumulate.

Environmental measures to be implemented

1. To conduct a cleanup of the accumulated sedimentary material to permit the free flow of water in natural drainage systems. When the road cuts into a wetland lagoon, such as is the case with the Remolinito Grande lagoon, it will be necessary to avoid cutting off free circulation of water, allowing drains and other means to permit the water that usually flows into the lagoon to flow freely on both sides of the Route.
2. To improve drainage structures and land fills to avoid impacts on both.
3. Continue with civic works for the protection of slope surfaces through the placing of geo-textiles and improvement of the angle of slopes and drainages.

c. Loss of trees and bushes along river margins due to flooding

Source of impact/risk

The placement of some drainage systems and temporary bridges could be associated to the alteration of specific points in aquatic ecosystems and the modification of natural drainage systems in the area. This impact is very punctual, since it was observed in few sites (at least 4 between Border Marker 2 and Infiernito River).

An accumulation of water is generated which forms a kind of dam on the river margin forest vegetation, causing the loss of some specimens. This is due to the fact that drains and drainage tubes became obstructed, leading to the flooding of these small ecosystems.

Environmental measures to be implemented

1. To promote a good drainage of waters in the sites mentioned, through placement of an adequate drainage system, or lowering the levels of drains to avoid the accumulation of waters and alteration of the road itself. Once excess water is drained, it is suggested that the area simply be allowed to recover naturally through the secondary regeneration of native vegetation.

***d.* Occurrence of landslides and slope erosion affecting the forest borders of the road**

Source of impact/risk

Due to the cuts on the terrain of the route where there is forest vegetation along the border, erosion in layers is caused, which in turn causes small trees to fall due to the loss of root strength.

Environmental measures implemented

In recent months the roadside slopes along the route have been protected along with the drainage systems at the same sites, to avoid landslides.

Environmental measures to be implemented

1. Continue with civil works for the protection of the surface of slopes along the road making use of geo-textiles and by improving the slant of slopes and drains.
2. To evaluate the technical possibility of modifying the route designated for Route 1856 at the point called Infiernillo to include the use of local roads built on less sloping terrain, tracing the road some km. to the south, where there are open areas and settlements with more favorable topographic conditions.

e. Impact on wetland ecosystem (due to drainages and landfills)

Source of impact/risk

Due to the placement of drains, landfills and sub-surface layers and the rolling surface of the road. It corresponds with the alteration of the ecosystem at some points of the designated path due to sedimentation and drainage in some wetlands along the Route.

Environmental measures to be implemented

1. To improve drainage structures and landfills with the purpose of avoiding impacts.
2. To allow recovery of the natural ecosystem.
3. To establish a monitoring plan along the designate path of Route 1856 with the aim of verifying wetland recovery and prevent the cutting of Yolillo and other tree species associated with wetlands due to activities of the local population.

f. Impact on structural connectivity

Source of impact/risk

Due to the land and vegetation clearing at some sites along the route path, it was necessary to eliminate some trees, in sections where roads were not previously present.

This loss of plant cover in some specific points of the Route, could generate an alteration of the structural connectivity due to the cutting down of trees.

Environmental measures implemented

In recent months a reforestation plan with thousands of trees has been put into effect as a mitigation measure proposed by the Ministry of the Environment(MINAE). This plan is providing good results in terms of growth and maintenance of the trees, and it has involved community participation in planting and protection activities**.**

Environmental measures to be implemented

1. To continue to implement reforestation activities with native species.
2. To promote natural regeneration and ecological restoration to improve connectivity among populations, species and communities.
3. To establish a monitoring plan along Route 1856 with the aim of verifying the recovery of connectivity.

6.5.1.2 Aquatic flora and fauna

g. Potential impact on aquatic habitat

Source of impact/risk

The construction of drains and building cement structures in some streams where bridges are located along the Route. This impact was identified in very few sites.

Environmental measures to be implemented

1. To consolidate the civil engineering works along the Route at impacted sites.
2. To avoid applying cement along the bottom of streams below drains and bridges.
3. To conduct a monitoring plan of aquatic habitat conditions in the streams below drainage systems and bridges.

h. Possible impact of the micro-habitats and substrata of aquatic macro-invertebrates due to filling of interstitial gaps with sediment

Source of impact/risk

Land movements, slopes formation and landfills originated instability in slopes at some sites where the degree of slant is strong, where there has been an increase in the surface runoff and sedimentation has increased along some bodies of water close to some sections of the Route.

The previous conditions originate a filling of sediment in rock cavities that modifies the temporal substratum where aquatic macro-invertebrates normally live.

Environmental measures implemented

In recent months a reforestation plan with thousands of trees has been put into effect as a mitigation measure proposed by the MINAET. This plan is providing good results in terms of growth and maintenance of the trees, and it has involved community participation in planting and protection activities**.**

Environmental measures to be implemented

1. To consolidate civil works to improve slopes and drainage systems as soon as possible, especially on unstable slopes to avoid sedimentation of aquatic media.
2. To continue with reforestation activities using native species of the region.
3. To promote natural regeneration and ecological restoration along the margins of rivers and streams.
4. To establish a monitoring plan along the path of Route 1856 in order to verify the state of the substrata of streams.

i. Potential Impact onTaxonomic Abundance and Richness

Source of impact/risk

Generated by sedimentation in the waters, the decrease in the vegetal material that flows into aquatic media and the decrease of shade which causes an impact on the abundance of species in the bodies of water.

Environmental measures implemented

In recent months a reforestation plan with thousands of trees has been put into effect as a mitigation measure proposed by the MINAET. This plan is providing good results in terms of growth and maintenance of the trees, and it has involved community participation in planting and protection activities.

Environmental measures to be implemented

1. To consolidate civil works to improve slopes and drainage systems as soon as possible, especially on unstable slopes to avoid sedimentation of aquatic media.
2. To continue with reforestation activities using native species of the region.
3. To promote natural regeneration and ecological restoration along the margins of rivers and streams.
4. To establish a monitoring plan along the path of Route 1856 in order to verify the status of biodiversity.

j. Potential Impact on the Quality of Water due to Turbidity

Sources of impact/risk

Land movements, the building of slopes and landfills generate an increase in superficial runoff and sedimentation in some bodies of water close to sections of the Route.

Environmental measures implemented

In recent months a reforestation plan with thousands of trees has been put into effect as a mitigation measure proposed by the MINAET. This plan is providing good results in terms of growth and maintenance of the trees, and it has involved community participation in planting and protection activities.

Environmental measures to be implemented

1. To consolidate civil works to improve slopes and drainage systems as soon as possible, especially on unstable slopes to avoid sedimentation of aquatic media.
2. To continue with reforestation activities using native species of the region.
3. To promote natural regeneration and ecological restoration along the margins of rivers and streams.
4. To establish a monitoring plan along the path of Route 1856 in order to verify the status of substrata in the rivers and streams.

6.5.1.3 Paisaje

k. Impacton landscape in some sections of the Route due to construction activities

Sources of impact/risk

Due to land clearing and vegetation removal along sections of the route, it was necessary to eliminate some trees specifically in areas where no previous roads existed.

Despite the fact that the route runs mostly (74%) on pre-existing roads and areas with minimal slopes, at some specific points it is possible to observe exposed surfaces on slopes and road cuts on the terrain, mainly between Border Marker 2 and the mouth of the San Carlos River.

Environmental measures implemented

In recent months a reforestation plan with thousands of trees has been put into effect as a mitigation measure proposed by the MINAET. This plan is providing good results in terms of growth and maintenance of the trees, and it has involved community participation in planting and protection activities**.**

Environmental measures to be implemented

1. To reforest in front of all road cuts that are visible from the right margin of the San Juan River using various species per site, planting parallel rows in front of the cuts, starting from the river margin, or the area alongside the slope and going up, with species that are short in height and have a wide canopy, such as sotacaballo and balsamo (planted sparsely to maintain a wide treetop), followed by medium height trees such as guabillo or balsa and other species of high profile, such as cebo, botarrama and roble coral, in such way that the density of the trees provide the necessary foliage cover from a few meters above ground to an approximate height of 30 meters.
2. To promote the growth of grasses on the surface of slopes. It was observed along the Route that the species of native and adapted gramineae known as sainillo (*Axonopus sp*) and rotana (*Ischaemun indicum*), are covering a good portion of the road cuts of limited height in the area in an efficient manner, avoiding rainfall from falling directly on slope surface.
3. To promote the identification of landscapes and ecosystems in different sections of the Route as an incentive to tourism.

6.6 Environmental Management Plan – Environmental Adequacy Plan (PAA)

According to the EDA guide (SETENA Resolution No. 2572-2009) environmental action programs that follow are the most important final products since their function is to adapt the implementation and management conditions, in this case Route 1856, to an environmental focus perspective. This chapter is called the Environmental Management Plan which includes the Environmental Adequacy Plan, formulated on the basis of a diagnostic study, description and analysis of the Project's own characteristics and its natural environment.

The PAA summarizes in concrete fashion all aspects developed in previous chapters in their thematic components, and for this reason it is presented as a summary chart, so that it can be seen in simplified manner. In this sense the PAA presented in this EDA seeks to strengthen the

environmental advances made presently in the design and construction of Route 1856.

Furthermore, in such Resolution it is stated that the PAA suggests actions and control procedures necessary to guarantee the appropriate application of environmental measures required for the construction of the Project, in such a way that an adequate protection of the quality of the environment is obtained, in accordance with the legislation, requirements and norms which hold during the operation of the Project.

It is necessary to point out that Chart 26 presents a summary of the PAA. However the column that makes reference to the Cost of the Measure has been omitted. This is due to the fact that some of the environmental measures were implemented some months ago. Another factor that is an obstacle or difficulty is the fact that the quantification of costs is waiting for the final design of the Route and some bridges are still in process of being contracted by the Government of Costa Rica; a process that does not facilitate the definition of costs.

Finally, the organization responsible for the execution of environmental measures is the National Transportation Council (CONAVI) with the collaboration of the MINAET and other government organizations assigned to the construction and supervision of the Route.

Chart 26: Environmental Adequacy Plan (PAA).

Environmental Diagnosis Assessment (EDA) ***Route 1856 Project – Ecological Component*** ***Environmental Adequacy (PAA)***							
Environmental Aspect	***Environmental Impact***	***Corrective-Compensatory Measures***	***Environmental Goals***	***Environmental Performance Indicators***	***Sampling location and frequency***	***Interpretation and feedback***	***Responsible of execution***
Cleaning and logging of some sections of the right of way in Route 1856	Partial deforestation along the right of way and adjacent areas	To strengthen reforestation plans in existence with the planting of trees in areas where it is not necessary to cover road cuts, reforesting with scarce native species, threatened or endemic, avoiding exotic plants or species that are not present locally. It is recommended to mix species, simulating the forest diversity and that species include an approximate proportion of 50% of those common in the area, which are now decimated, such as the manú, cocobolo and jícaro. The other 50% should include species that are planted commonly in reforestation plans in the area. Priority areas should be sites with undulating slopes or strongly undulated and in the border strand along the San Juan River, and other rivers or creeks in the area of Route 1856.	To ensure protection to existing trees in the right of way (50m) along Route 1856 Natural vegetation regeneration along Route 1856 Improvement of scenic value along road construction.	Number of trees reforested. Plant inventory along the road. Results from the monitoring and maintenance plan. Photo record with signs along the road.	Every 6 months. Along all Route 1856.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	CONAVI - MINAET
		To allow the natural regeneration of secondary vegetation where it appears aggressively, not cutting it down to plant trees, or making use of arboreal species as shade to favor species that are intolerant to the sun or which grow better in the shade in their early growth stages, such as the manú, pinillo or the almendro de montaña, for example. At sites with very slanted slopes it is advisable to allow secondary growth vegetation to re-establish itself, if possible. Given the fact that the total loss of natural forest cover was quantified at 83 hectares, it is suggested that an area similar to that deforested be allowed to recover its natural secondary vegetation, in a section lying next to the road, giving priority to hilly areas adjoining the San Juan River, as a way to compensate the native ecosystem, since commonly reforestation programs do not propitiate ecosystems such as those required to maintain native biodiversity. With the purpose of verifying the existence of tree species that are threatened within the right of way of the Route, it would be advisable to establish a forest inventory of forest species found along the Route					
		To establish a protection and maintenance plan for trees identified as endangered or banned.					
		To conduct periodic monitoring along the route design to avoid squatter incursions in the neighboring areas.					
		To promote the identification of different sections and ecosystems along the route as a tourism incentive.					
Land removal, establishment of slopes and	Partial sedimentation on wetland margins	To conduct a cleanup of the accumulated sedimentary material to permit the free flow of water in natural drainage systems. When the road cuts into a wetland lagoon, such as is the case with the Remolinito Grande lagoon, it will be necessary to avoid cutting off free	To start a sediment cleaning process as well as construction of civil works	Photo record of Works developed.	At sites identified as wetlands along	A record of all technical reports and results will be	CONAVI

Environmental Diagnosis Assessment (EDA) *Route 1856 Project – Ecological Component* *Environmental Adequacy (PAA)*							
Environmental Aspect	***Environmental Impact***	***Corrective-Compensatory Measures***	***Environmental Goals***	***Environmental Performance Indicators***	***Sampling location and frequency***	***Interpretation and feedback***	***Responsible of execution***
landfills	neighboring to Route 1856	circulation of water, allowing drains and other means to permit the water that usually flows into the lagoon to flow freely on both sides of the Route. To improve drainage structures and landfills to avoid impacts on wetlands Continue with civic works for the protection of slope surfaces through the placing of geo-textiles and improvement of the angle of slopes and drainages.	which avoid sediment input to wetlands.	Verification report on the works´ efficiency.	the Route. . They should be developed during the process of improvement of construction works in the short term.	kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	- MINAET
Location of some drainage systems and temporary bridges	Loss of trees and bushes along river margins due to flooding	To promote a good drainage of waters in the sites mentioned, through placement of an adequate drainage system, or lowering the levels of drains to avoid the accumulation of waters and alteration of the road itself. Once excess water is drained, it is suggested that the area simply be allowed to recover naturally through the secondary regeneration of native vegetation.	To avoid tree loss due to flooding in areas with poor natural drainage. To start an improvement process in drainage systems along the Route.	Report on improvements and construction of drainages and bridges	At those sites along the Route where water accumulation and tree loss were identified. They should be developed during the process of improvement of construction works in the short term.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	CONAVI - MINAET
Land removal, establishment of slopes	Occurrence of landslides and slope erosion affecting the forest borders of the road	Continue with civil works for the protection of the surface of slopes along the road making use of geo-textiles and by improving the slant of slopes and drainages. To evaluate the technical possibility of modifying the route designated for Route 1856 at the point called Infiernillo to include the use of local roads built on less sloping terrain, tracing the road some km. to the south, where there are open areas and settlements with more favorable topographic conditions.	To prevent landslides in areas with high slopes. To ensure forest cover protection around slopes and land cuts along the Route. To evaluate road design.	Report on number of slopes intervened and construction works implemented..	At those sites along the Route where unstable slopes were identified. They should be developed during the process of improvement of drainages, bridges and slopes along the Route in the short term.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	CONAVI - MINAET
Land removal, construction of drainages, landfills, sub-base and rolling surface	Impact on wetland ecosystem (due to drainages and landfills)	To improve drainage structures and landfills with the purpose of avoiding impacts. To allow recovery of the natural ecosystem. To establish a monitoring plan along the designate path of Route 1856 with the aim of verifying wetland recovery and prevent the cutting of Yolillo and other tree species	Vegetation regeneration along Route 1856 Scenic value improvement. To start a sediment cleaning process and construction	Photo record of the works developed. Verification report on the works´ efficiency.	At sites identified as wetlands along the Route. They should be developed during the process of	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new	CONAVI - MINAE

Environmental Diagnosis Assessment (EDA) Route 1856 Project – Ecological Component Environmental Adequacy (PAA)							
Environmental Aspect	**Environmental Impact**	**Corrective-Compensatory Measures**	**Environmental Goals**	**Environmental Performance Indicators**	**Sampling location and frequency**	**Interpretation and feedback**	**Responsible of execution**
		associated with wetlands due to activities of the local population.	works which avoid sediment input to wetlands.		improvement of construction works in the short term.	timeframes established.	
Cleaning and logging of some sections of the right of way in Route 1856	Impact on structural connectivity	To continue to implement reforestation activities with native species. To promote natural regeneration and ecological restoration to improve connectivity among populations, species and communities. To establish a monitoring plan along Route 1856 with the aim of verifying the recovery of connectivity.	To start a reforestation process that allows connectivity improvement for different ecosystems in various sections along the Route.	Number of trees reforested. Plant inventory along the Route. Results from the monitoring plan.	Every 6 months. Along all Route 1856.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	CONAVI - MINAET
Construction of some drainages and temporary bridges	Potential impact on aquatic habitat	To consolidate the civil engineering works along the Route at these sites. To avoid applying cement along the bottom of streams below drainages and bridges. To conduct a monitoring plan of aquatic habitat conditions in the streams below drainage systems and bridges.	Improvement in waterways conditions.	Photo record of the works developed. Verification report on the works´ efficiency.	Every 6 months. Along all Route 1856.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	CONAVI - MINAET
Land removal, establishment of slopes and landfills	Possible impact of the micro-habitats and substrata of aquatic macro-invertebrates due to filling of interstitial gaps with sediment	To consolidate civil works to improve slopes and drainage systems as soon as possible, especially on unstable slopes to avoid sedimentation of aquatic media. To continue with reforestation activities using native species of the region. To promote natural regeneration and ecological restoration along the margins of rivers and streams. To establish a monitoring plan along the path of Route 1856 in order to verify the state of the substrata of streams sampled in this study	To avoid sediment input to waterways as a result of construction of the road.	Photo record of the works developed. Verification report on the works´ efficiency. Number of trees reforested. Results of the monitoring plan.	At sites along the Route where unstable sloped were identified. They should be developed during the process of improvement of drainages, bridges, and slopes in the short term.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	CONAVI - MINAET
Land removal, establishment of slopes, cleaning and logging	Potential impact on taxonomic abundance and richness	To consolidate civil works to improve slopes and drainage systems as soon as possible, especially on unstable slopes to avoid sedimentation of aquatic media. To continue with reforestation activities using native species of the region.	To avoid sediment input to waterways as a result of construction of the road.	Photo record of the works developed. Verification report on	At sites along the Route where unstable sloped were identified.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment	CONAVI - MINAET

Environmental Diagnosis Assessment (EDA) ***Route 1856 Project – Ecological Component*** ***Environmental Adequacy (PAA)***							
Environmental Aspect	***Environmental Impact***	***Corrective-Compensatory Measures***	***Environmental Goals***	***Environmental Performance Indicators***	***Sampling location and frequency***	***Interpretation and feedback***	***Responsible of execution***
		To promote natural regeneration and ecological restoration along the margins of rivers and streams.		the works´ efficiency. Number of trees reforested. Results of the monitoring plan.	They should be developed during the process of improvement of drainages, bridges, and slopes in the short term.	of these measures, it should be justified and new timeframes established.	
		To establish a monitoring plan along the path of Route 1856 in order to verify the status of biodiversity.					
Land removal, establishment of slopes, cleaning and logging	Potential impact on the quality of water due to turbidity by sediments	To consolidate civil works to improve slopes and drainage systems as soon as possible, especially on unstable slopes to avoid sedimentation of aquatic media.	To avoid sediment input to waterways as a result of construction of the road.	Photo record of the works developed. Verification report on the works´ efficiency. Number of trees reforested. Results of the monitoring plan.	At sites along the Route where unstable sloped were identified. They should be developed during the process of improvement of drainages, bridges, and slopes in the short term.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	CONAVI - MINAET
		To continue with reforestation activities using native species of the region					
		To promote natural regeneration and ecological restoration along the margins of rivers and streams.					
		To establish a monitoring plan along the path of Route 1856 in order to verify the status of substrata in the rivers and streams, and suspended solids					
Land removal, establishment of slopes, cleaning and logging	Impact on landscape in some sections of the Route due to construction activities	To reforest in front of all road cuts that are visible from the right margin of the San Juan River using various species per site, planting parallel rows in front of the cuts, starting from the river margin, or the area alongside the slope and going up, with species that are short in height and have a wide canopy, such as sotacaballo and balsamo (planted sparsely to maintain a wide treetop), followed by medium height trees such as guabillo or balsa and other species of high profile, such as cebo, botarrama and roble coral, in such way that the density of the trees provide the necessary foliage cover from a few meters above ground to an approximate height of 30 meters.	Scenic value improvement along the Route 1856. Natural vegetation regeneration along Route 1856.	Number of trees reforested. Results of the monitoring plan and maintenance. Photo record with signs along the road.	Every 6 months. Along all Route 1856.	A record of all technical reports and results will be kept for MINAE inspections. In the case of not fulfillment of these measures, it should be justified and new timeframes established.	CONAVI - MINAET
		To promote the growth of grasses on the surface of slopes. It was observed along the Route that the species of native and adapted gramineae known as sainillo (*Axonopus sp*) and rotana (*Ischaemun indicum*), are covering a good portion of the road cuts of limited height in the area in an efficient manner, avoiding rainfall from falling directly on slope surface.					
		To promote the identification of landscapes and ecosystems in different sections of the Route as an incentive to tourism.					

Note: Information about costs of these measures is not included since some environmental measures have been already implemented for several months. Furthermore, the final road design contract, including location of bridges, is still to be awarded by the Costa Rican government.

7 Conclusions y recommendations

7.1 Conclusions

1. The Route 1856 project consisted in the construction of a ballast road that starts in the site of San Jerónimo de Los Chiles and runs all the way to the site of Delta 7 (better known as Delta Costa Rica). Route 1856 is 159,7 km. long. A 63 % of the road designed (101.5m) is made up of roads and access paths that have existed for over 30 years. The remaining 35,9% (57,4 km.) of the Route corresponds to roads that are new and were established in order to join existing roads. Nevertheless, the present study contemplates only the design route that runs parallel to the San Juan River with a length of 108,2 km of the total length of the Route.
2. For purposes of building the Route, and as is common in this type of project, it was necessary to carry out several important secondary works. Among them were the clearing of terrain, the building up of slopes, placing gutters and drains, as well as laying the base of the road and rolling surface.
3. The environmental aspects related to the construction activities were:
    a. Clearing the land and vegetation in some sections of the route design: this activity is associated with the elimination of plant cover along sections of the route where no roads existed previously.
    b. Land movements, slope formation and landfills: could generate unstable slopes in some points where the slope is very steep. The increase in surface water runoff and contribution of sediments to some nearby bodies of water and the alteration of landscape along the Route.
    c. Installation of drainage systems and temporal bridges: this factor could be associated to the alteration of aquatic ecosystems at specific points and the modification of natural drainage systems in the area.
    d. Placement of landfills, base layers and rolling surface on the road: this activity is related to a potential contribution to the sedimentation of some bodies of water close to the Route.

7.1.1 Terrestrial Biology

1. In the study area, two life zones were found: very humid pre-montane basal transition forest and very humid tropical forest. The very humid tropical forest is the most representative life zone in the northern part of Costa Rica and adds up to 61% of the territory in the lowlands of Sarapiquí and San Carlos. It is the life zone that provides the main connecting habitat between the South Atlantic watershed of Nicaragua and the Volcanic Central Range of Costa Rica.
2. Within the Project area various ecosystems, or ecological associations, were identified, among them: forest associations (altered primary and secondary forests), wetlands systems, riparian systems and Yolillo palm associations.

3. During the last decades and due to the pressure of the agricultural frontier, many of the primary forests ecosystems in the border area have been altered and/or destructed to later convert into natural forests. Even so, these forests present a high floristic diversity.
4. Regarding the wetlands systems, there is in the area a large number of rivers, streams, channels and lagoons where the vegetation is typical of lacustrine and palustrine wetlands.
5. The area of the Project was determined to be 10.475 hectares based on interpretation of aerial photos taken before and after the construction of the Route, but the road project only partially affected 4.921,3 hectares, which represents 47% of the total.
6. This evaluation of the plant vegetation along the route, led to a quantification as follows: for purposes of clearing of the terrain where the road route was laid, some 14,9 hectares of secondary forests were cut down and 68,3 hectares of primary forests were altered, which represents 4,2% and 19,5% of the altered area of the Route design.
7. As complement, 2,3 hectares were altered that are not forests but natural systems of the wetland type. In the field it was possible to see that the road opening was done mostly in open areas(74%) that were not forested. In cases where forests were cut down, it was in areas where no open lands were available to establish the route.

7.1.2 Aquatic Biology

1. To assess the effect of the construction on the 1856 Route on the aquatic ecosystems that run across the road and empty into the San Juan River, ten lotic bodies of water were selected (creeks, channels, rivers), the structure of the communities was characterized and the quality of water evaluated using the BMWP index (MINAE-S, 2007) focusing on the macro-invertebrates aquatic groups as indicator species.
2. In each of the bodies of water two sampling points were located, one upstream (without direct influence) where the road crosses the body of water sampled and the other downstream (direct influence), for a total of 20 sampling locations.
3. In general, the aquatic community of most sites sampled had a very low diversity and richness in taxa. This result is possibly due to three reasons: current volume, turbidity-sedimentation and type of substrata.
4. With the values of abundance and richness of the taxa obtained for the upstream sites (upstream from the Route), and the sites with influence (downstream from the Route), in half of the cases it is possible to state that bio-indicators did not present evident information that indicated impact on the community of macro-invertebrates, since values were too variable.
5. The lattercould be caused by 2 factors: 1) degradation of the quality of the habitat as a consequence of some of the activities that were carried out in the construction of the Route, such as the movement of earth and cutting down of river vegetation, and, 2) sedimentation processes in the rivers due to unstable slopes and land fills that erode due to rainfall.
6. An aquatic environment once altered is subject to re-colonization periods that can vary from a few days to weeks or months, depending on the nature and reach of the alteration. The response of bio-indicators to the effects of the construction of Route 1856 on aquatic ecosystems was imperceptible in some sampling sites, possibly because the aquatic communities have already recovered.

7. Field sampling occurred approximately one year-and-half after the road construction works, and it is probable that during this period the communities were able to stabilize. It is also important to take into account that these bodies of water are in low-lying areas and that they receive large quantities of sediment all year round from the upper watershed, so that aquatic fauna should be adapted to receive high levels of sediments in the water.
8. The quantity of sediment that the Route contributes is not sufficient to cause a significant impact on the bio-indicators studied in the sample sites.
9. The presence of groups sensitive to the alterations of the aquatic habitat is a good signal, since these indicators often disappear when there are strong alterations in the aquatic habitat, especially if the effect is persistent over time, since it does not permit the sensitive taxa to re-colonize the bodies of water. The finding of sensitive families in practically all sampled sites, up and downstream from the Route, can be interpreted as a positive sign of recovery and of a minor impact of the construction on the environmental conditions at the points of study. Only two sites did not show the presence of macro-invertebrates considered sensitive.
10. It should also be taken into account that the sampling for bio-indicators was done on rivers that flow into the San Juan River, so that the impacts that were detected due to the construction works of the Route on the aquatic environment, such as the modification of substrata and sedimentation, are local level events.
11. These bodies of water received a direct influence from the construction works, therefore these results do not overlap to the San Juan River, since the latter is of a superior order, with a greater volume of water than present at the sampled sites. The section of the San Juan that runs parallel to this road is found in the lower part of the watershed where the quantity of sediments is naturally high, and thus it is thought that the impacts of the Route construction on the organisms that live in the San Juan River could have been minimal and very diffuse, taking into account the water volume of the river, as a receptor body.
12. In order to be able to evaluate with greater certainty if the construction works of the Route created a level of sedimentation that could generate an effect on the aquatic fauna of the San Juan River, and the tributary streams of the study area, it is first necessary to determine and validate the thresholds of sedimentation that could affect the species found in these rivers, due to the fact that there exists no information for the aquatic organisms in the study area.
13. It would also be necessary to determine and validate the thresholds of mortality and morbidity for the species found in those rivers, as well as the levels of tolerance to sedimentation, to better evaluate if the construction of Route 1856 has an effect on the aquatic fauna of the San Juan River. This due to the fact that there is no information on the aquatic organisms of the study area. To establish these values it would be necessary to conduct periodic analyses over a long term that evaluate the tolerance of species and macro-invertebrates to different qualities of sediments, and thus be able to determine at what point the aquatic organisms began to die or experience a significant reduction in abundance and diversity.

7.1.3 Tourism

1. The study area specifically does not offer conditions for tourism development, nor has it ever been an area of tourism development. To date, the stretch between Border Landmark 2 and Delta Costa Rica does not have any kind of tourism facility neither on the right nor on the left margin of the San Juan River. The only site where there are services and facilities is Delta Cabins, and these are mostly for national visitors. Towards the two extreme areas of the river, infrastructure and facilities improve, concentrating in the towns of San Carlos and San Juan del Norte.
2. It is important to note that tourism axes have concentrated in the endpoints of the river. In the case of Nicaragua, it offers services in San Carlos and neighbouring areas, and in Greytown, San Juan and its proximities. The remainder of the river, mainly the margin under study, has no services other than fluvial transportation from site to site. Tourism services in the study area are extremely limited accounting for 3,54% of the tourism nationwide (PNDTS 2011-2020). The San Juan River department is among the poorest in the country, and is therefore one of the regions of the country with least tourism services.
3. The city of San Carlos is the tourism distribution centre for the San Juan River (El Castillo, Sábalo, Solentiname Islands), but it does not offer visitors the necessary physical infrastructure to meet their needs. Visitation to this area does not reach beyond an estimated 10,000 visitors per year, a very small number to be able to consider developing a competitive and consolidated tourism.
4. Some of the lodges that have appropriate facilities of a middle level, well integrated to the natural surroundings, are developing tourism products focused on international visitors with an emphasis on eco-tourism: wildlife observation, tours within the reservations, specialized nature paths, fishing, etc. However, some of these have been unable to consolidate a visitation level that would allow them to reach their point of equilibrium, so that their services are seasonal and not year-round.
5. Tourism services concentrate mainly on nature observation, nature walks, boat tours and fishing. These activities concentrate in Sábalo, El Castillo and the Indio-Maíz Refuge and neighboring areas.
6. Even though sportfishing activities are widely provided in the region of San Carlos and neighboring areas such as El Castillo and Sábalo, no commercial or fishing activities were identified along the river for the study area. Fishing activities from Border Mark 2 to Delta Costa Rica is sporadic, subsistence fishing.
7. The tourism potential of the region is sufficient to justify attracting international visitors. However, infrastructural conditions, the state of access routes, the existing services and products offered, the quality of the existing offer, a weak image for the region, information and commercialization mechanisms of an incipient nature, are not sufficiently satisfactory to attract more visitors.
8. The previously mentioned factors, in addition to a climate of instability and insecurity in the region, generated by images of continuous border disputes between Costa Rica and Nicaragua, do not favor the kind of private investment that could strengthen tourism in the region.
9. All the same, Nicaragua (PNDTIS 2011-2020) points strongly to the San Juan River department as one of its priority destinations to strengthen and raise nature tourism in

the country. To date, there are no significant changes in the flow of visitors. In some instances, the contrary is what is taking place, with important decreases in tourism visitation being reported, (see Chart 1).

10. The growth in visitation to San Carlos could increase further, though slightly, due to the new road that connects Managua with San Carlos, which has reduced travel to 4.5 hours. However, this new access seems to be attracting mainly local tourism and backpackers.
11. The use of fluvial transportation means that tourists travel mainly on public transportation services which have pre-established itineraries with very accessible costs (see Annex 1). On the other hand, private transportation services are costly and practically non-existent.
12. The profile of tourists who visit the region and specially those who visit across the San Juan River is mostly that of backpackers who are willing to pay minimally for very basic services.
13. To date, navigation on the river, requires extra investment due to the additional taxes that Costa Rican boats must pay when reporting to Nicaraguan authorities in San Carlos, in addition to the less than friendly requirements placed on tourists; conditions that add to the sense of insecurity and distrust in trying to conduct organized tourism.
14. The effect of the construction of Route 1856 has no direct impact on tourism in recent years.

7.1.4 Ecological Connectivity

1. The analysis of the landscape structure in the region makes evident some of the gaps present in the goals of biodiversity conservation and in ecosystems on the Atlantic Watershed of Costa Rica. On the other hand, there is also evidence of a dynamic and heterogeneous environment that can impact processes of ecological adaptation, succession, maintenance of the diversity of species, community stability, competition, interaction between predators and prey, parasitism, epidemics and other stochastic events.
2. Identification of connectivity routes and the important connectivity areas in the landscape of the study area, show that these are not related to the design of the route of the road, despite the fact that this access road to the border is located in the area of most forest cover in the study area. Likewise, it can be affirmed that the Route, due to the limited extension of the natural systems affected, has not originated a significant impact on the structural connectivity of the landscape of the study.

7.1.5 Identified Impacts

1. On the basis of the evaluation of the activities conducted by the Project, a series of impacts were identified, which are presented next:
    a. Cutting down of the forests in the right of way of the road and neighbouring areas
    b. Partial sedimentation of wetland borders near the Route
    c. Loss of trees and bushes located on the margin of bodies of water, caused by flooding
    d. Landslides and erosion of slopes affecting the forested side of the Route.
    e. Alteration of the wetlands ecosystems (drainage and landfill)

f. Alteration of the structural connectivity

g. Possible alteration of aquatic habitat

h. Possible alteration of micro-habitats and aquatic macro-invertebrate substrata due to filling of interstitial areas with sediment.

i. Possible decrease in taxonomic abundance and richness

j. Potential impact on the quality of water due to turbidity

k. Landscape alteration due to the construction

2. Taking into account the results of the evaluation of the Matrix of Important Environmental Impacts, only 8 irrelevant impacts were identified, and 3 moderate impacts. These show very particular characteristics, among them:

   a. None of the impacts is recurrent along the Route; these have been identified in very specific points along the Project.

   b. All impacts show a degree of low or medium intensity on the environment.

   c. All impacts have a uniform value, between the values of 20 to 34, which indicates homogeneity in the low incidence of the impacts along the Route.

7.2 Recommendations

A series of recommendations follow that have been previously considered in the present study, in this instance presented as a summary that advises the implementation of a number of activities as part of the measures of prevention, mitigation and improvement of environmental conditions in the area of the path of Route 1856.

1. To strengthen reforestation plans in existence with the planting of trees in areas where it is not necessary to cover road cuts, reforesting with scarce native species, threatened or endemic, avoiding exotic plants or species which are not present locally. It is advisable to mix species, simulating the forest diversity and that species include an approximate proportion of 50% of those common in the area which are now decimated, such as the manú, cocobolo and jícaro species. The other 50% should include species that are planted commonly in reforestation plans in the area. Sites with undulating slopes or strongly undulated and in the border strand along the San Juan River, and other rivers or creeks in the area of Route 1856, should be priority areas.

2. To allow the natural regeneration of secondary vegetation where it appears aggressively, not cutting it down to plant trees, or making use of arboreal species as shade to favour species that are intolerant to the sun or which grow better in the shade in their early growth stages, such as the manú, pinillo or the almendro de montaña, for example. At sites with very slanted slopes it is advisable to allow secondary growth vegetation to re-establish itself, if possible. Given the fact that the total loss of natural forest cover was quantified at 83 hectares, it is suggested that an area similar to that deforested be allowed to recover its natural secondary vegetation, in a section next to the road, giving priority to hilly areas adjoining the San Juan River, as a way to compensate the native ecosystem, since commonly reforestation programs do not propitiate ecosystems such as those required to maintain native biodiversity. With the purpose of verifying the existence of tree species that are threatened within the right of way of the Route, it would be advisable to establish a forest inventory of forest species found along the Route.

3. Establishment of an integrated land use plan in the region.
4. Establishment of a plan for protecting and maintaining trees identified as in danger of extinction or banned.
5. To promote the identification of different landscape sections and ecosystems along the route as an incentive for tourism.
6. To establish a protection and maintenance plan for trees identified to be in danger of extinction, or banned.
7. To clean up all accumulated sediments to allow the free path of water through natural drainage systems.
8. In circumstances when the road runs close to a wetland, as is the case of Remolinito Grande Lagoon, obstruction of the free flow of waters should be avoided, allowing free circulation through gutters and other means, so that the water that normally enters the wetland can flow freely on both sides of the road.
9. Improve the drainage structures and landfills to avoid alterations to wetlands.
10. Continue with civil works for the protection of slope surfaces through the application of geo-textiles and the improvement of slope angles and drainage systems.
11. To favor a good drainage of waters in the sites mentioned, through placement of an adequate drainage system, or lowering the levels of drains to avoid the accumulation of waters and alteration of the road itself. Once excess water is drained, it is suggested that the area simply be allowed to recover naturally through the secondary regeneration of autochthonous vegetation.
12. Evaluate the technical possibility of modifying the Route design at the point of Infiernillo to follow local roads built previously, deviating for some km. to the South, where there are settlements and open areas with topographic conditions that are more favourable to this type of project.
13. To establish a monitoring plan along the Route to verify the recovery of wetlands and prevent the cutting of trees by locals, as well as avoid squatter incursions in areas neighbouring the Route.
14. Continue to reforest using native species of the region.
15. To promote natural regeneration and ecological restoration to improve the connectivity between species, communities and populations.
16. To establish a monitoring plan along the Route to verify the recovery of connectivity.
17. Avoid using cement in river and stream beds under drainage gutters and bridges.
18. To conduct a monitoring plan of aquatic habitat conditions in the streams below drainage systems and bridges and to monitor the status of substrata of the monitored streams and take necessary measures.
19. Consolidate civil works to stabilize slopes as soon as possible, especially those considered unstable, to avoid sedimentation of aquatic environments.
20. To continue to implement reforestation activities with native species
21. To promote the natural regeneration and ecological restoration of river margins.

22. To establish a monitoring plan along Route 1856 with the aim of verifying the status of the substrata of streams that were monitored in this study.
23. Consolidate plant cover in the region as a means to prevent and recover the region from the historically unsound practices in the use of land prior to the intervention of Route 1856, particularly in spaces associated with the San Juan River margin, assuring that in the future, the population respects the conditions on the river margin.
24. Even though reforestation efforts implemented by CODEFORSA respect the use of species that are proper to the region, it is recommended that species of rapid growth be considered, in order to reduce visual impacts in the short run. In this process of reforestation it is also advisable to make use of species that may cover vertical spaces such that they may serve as visual barriers starting as low as 60 cm. onward.
25. It is basic to the process that the recovery of landscape be an integral part with participation of neighbouring communities, for which purpose it is recommended that initiatives include environmental education programs, civic education, entrepreneurship, self-development and others. The purpose is not only reforestation, but also that in this region of the country more than any other, a clear comittment is reached with a vision of a country that fights for sustainability and therefore for an integral and visionary action.
26. To generate development opportunities for local communities through the creation of policies that support local tourism. Eventually this could become a motor to generate tourism towards Nicaragua, as has been the intent in the past.
27. Improve safety and security conditions for inhabitants and for visitors in the region.

8 REFERENCES

Asamblea Legislativa. 1996. Ley Forestal. Decreto 7575. La Gaceta No 72. San José, Costa Rica.

Alabaster, J.S. & R. Lloyd. 1980. Water quality criteria for Freshwater fish. London: Butterworths.

Astorga, A., J.A. Fernández, G. Barboza, L. Campos, J.Obando, A. Aguilar& L.G. Obando. 1991. Cuencas sedimentarias de Costa Rica: evolución geodinámica y potencial de hidrocarburos. Revista Geológicade América Central 13: 25-59.

Astorga, A. 1992. Descubrimiento de corteza oceánica mesozoica en el norte de Costa Rica y el sur de Nicaragua. Revista Geológicade América Central 14: 109-112.

Astorga, A. 1997, El puente-istmo de América Central y la evolución de la Placa Caribe (con énfasis en el Mesozoico). Profil 12: 1-202.

Barquero, R., W. Rojas, R. Mora-Amador& A. Vargas. 2013. Informe anual de sismos sentidos y actividad volcánica 2012. San José, Costa Rica: Red Sismológica Nacional. Universidad de Costa Rica – Instituto Costarricense de Electricidad.

Bergoeing, J.P., L.G. Brenes, R. Protti, R. Arce, L.G.Artavia, D. Salas, M. Carrillo. 1997. Atlas geomorfológico del Caribe de Costa Rica. Escala 1:350000. San José, Costa Rica: Escuela de Geografía, Universidad de Costa Rica.

Bergoeing, J.P., L.G. Brenes, R. Protti, R. Arce, L.G. Artavia, D.Salas& M. Carrillo. 2010. Atlas geomorfológico del Caribe de Costa Rica. Escala 1:1000000. San José, Costa Rica: Escuela de Geografía, Universidad de Costa Rica.

Bolaños, R.& V. Watson. 1993. Mapa Ecológico de Costa Rica. Escala 1:200.000. San José, Costa Rica: Centro Científico Tropical.

Bravo, J.& L. Ocampo. 1993. Humedales de Costa Rica. Heredia, Costa Rica: Universidad Nacional / UICN.

Bussing, W. 1976. Geographic distribution of the San Juan Ichthyofauna of Central America with Remarks on its origin and Ecology. In T. B. Thorson (ed). Investigations of the ichthyofauna of Nicaraguan Lakes. Universidad de Nebraska-Lincoln, 157–175.

Bruton, M.N. 1985. The effects of suspensoids on fish. Hydrobiologia 125: 221–241.

Bussing, W. 1998. Peces de las aguas continentales de Costa Rica. San José, Costa Rica: Editorial de la Universidad de Costa Rica.

Bussing, W. 2002. Peces de las aguas continentales de Costa Rica. San José, Costa Rica:Editorial de la Universidad de Costa Rica.

Carrillo, E., G. Wong & J. Sáenz. 2002. Mamíferos de Costa Rica. Heredia, Costa Rica:Instituto Nacional de Biodiversidad.

Centro Científico Tropical. 1996. Inventario de vegetación en el Proyecto MineroCerro Crucitas. Placer Dome de Costa Rica S.A.

Centro Científico Tropical. 2008. Ficha informativa Humedales de Ramsar. Refugio Nacional de Vida Silvestre Mixto Maquenque. San José, Costa Rica: Centro Científico Tropical.

Connolly, N. & R. Pearson. 2007. The effect of fine sedimentation on tropical stream macroinvertebrate assemblages: a comparison using flow-through artificial stream channels and recirculating mesocosms. Hydrobiologia 592:423–438.

Corredor Biológico Mesoamericano. 2012. El Corredor Biológico Mesoamericano: una plataforma para el Desarrollo Sostenible regional. Managua, Nicaragua: Proyecto para la Consolidación del Corredor Biológico Mesoamericano.

COSEFORMA. 1992. Mapa de cobertura forestal en la Zona Norte. San José, Costa Rica: COSEFORMA.

Chassot, O., G. Monge, G. Powell, S. Palminteri, P. Wright, M. Boza, J. Calvo & C. Padilla. 2001. Corredor Biológico San Juan-La Selva para proteger la lapa verde.Ambientico 95: 13-15.

Chassot, O. & G. Monge. 2002. Corredor Biológico San Juan-La Selva. Ficha técnica. San José, Costa Rica: Centro Científico Tropical.

Chassot, O., G. Monge, A. Ruiz & L. Valerio. 2005. Ficha técnica binacional del Corredor Biológico El Castillo-San Juan-La Selva, Nicaragua-Costa Rica. Managua, Nicaragua: SICA / CCAD / CBM (Corredor Biológico Mesoamericano, Serie técnica 17).

Chassot, O., A. Mata & G. Monge (Eds.). 2006. Evaluación Ambiental del Refugio Nacional de Vida Silvestre Mixto Maquenque. San Pedro, Costa Rica: Centro Científico Tropical.

Chassot, O & G. Monge (Eds.). 2006. Plan de Manejo del Refugio Nacional de Vida Silvestre Mixto Maquenque, 2006-2010. Ciudad Quesada, Costa Rica: MINAE-SINAC-ACAHN / Centro Científico Tropical.

Chow, N. F. (s.f). Comportamiento del fitoplancton en los ríos tributarios del Río San Juan. Recuperado junio de 2013, de http://www.bvsde.org.ni/Web_textos/CIRA/Cira0005/09.pdf

Doppelt, B., M. Scurlock, C. Frissell & J. Karr. 1993. Entering the watershed: a new approach to save Americas' river ecosystems. Washington, DC: Island Press.

Downes, B.J., P.S. Lake, A. Glaister & N.R. Bond. 2006. Effects of sand sedimentation on the macroinvertebrate fauna of lowland streams: are the effects consistent? Freshwater Biology 51:144–160.

Elizondo, L.H. 1997. Estudios de cambio climático en Costa Rica, "Componente: vulnerabilidad de los bosques ante el cambio climático". Especies de fauna vulnerables. San José, Costa Rica: MINAE / Instituto Meteorológico Nacional (Informe técnico No 5).

Espinoza, M. 2008. Sondeo ecológico de las comunidades de peces tropicales en un área de explotación minera en Costa Rica. Revista de Biología Tropical 56 (4): 1971-1990.

Flores, E. 1992. Dipteryx panamensis, Árboles y Semillas del Neotrópico. Trees and Seeds from the Neotropics 1(1): 1-22.

Gazel, E., Alvarado, G., Obando, J., Alafaro, A., 2005. Geología y evolución magmática del arco de Sarapiquí, Costa Rica. Revista Geológicade América Central 32: 13-31.

Groom, M., D.B. Jensen, R.L. Knight, S. Gatewood, L. Mills, D. Boyd Heger, L.S. Mills, & M.E. Soulé. 1999. Buffer zones: benefits and dangers of compatible stewardship. In Soulé, M.E.& J. Terborgh (eds.). Continental conservation: scientific foundations of regional reserve networks. Washington, DC: Island Press, 171-197.

Hartshorn, G. 2002. Biogeografía de los bosques neotropicales. In Guariguata, M.& G. Kattan (comp.). Ecología y conservación de bosques neotropicales. Cartago, Costa Rica: Libro Universitario Regional, 59-81.

Hedrick, L. 2008. Evaluation of the impacts of highway construction on sediment and benthic macroinvertebrates in Appalachian Stream. Ph.D. thesis, Davis College of Agriculture, Forestry and Consumer Sciences at West Virginia University. West Virginia, USA.

Holdridge, L. 1987. Ecología basada en zonas de vida. San José, Costa Rica:Centro Científico Tropical.

Holdridge, L., L. Poveda, & Q. Jiménez. 1997. Árboles de Costa Rica. San José, Costa Rica: Centro Científico Tropical, (2da ed. actualizada).

INBIO. 2013. Instituto Nacional de Biodiversidad. Recuperado junio de 2013, de http://darnis.inbio.ac.cr/ubisen/FMPro?-DB=UBIPUB.fp3&-lay=WebAll&-error=norec.html&-Format=detail.html&-Op=eq&id=3971&-Find

IUCN, 2013. IUCN Global Species Programme Red List Unit. Recuperado junio de 2013, de http://www.iucnredlist.org/search

Janzen, D. (ed.). 1983. Costa Rican Natural History.Chicago & London: The University of Chicago Press.

Jiménez, Q. 1993. Árboles maderables en peligro de extinción en Costa Rica. San José, Costa Rica: Instituto Nacional de Biodiversidad, (2da ed. revisada y ampliada).

Jiménez, Q. 1997. Estudios de cambio climático en Costa Rica, "Componente: vulnerabilidad de los bosques ante el cambio climático". Especies de flora amenazadas o en peligro de extinción. San José, Costa Rica: MINAE / Instituto Meteorológico Nacional (Informe técnico No 6).

Kaller, M.D. & K.J. Hartman. 2004. Evidence of a threshold level of fine sediment accumulation for altering benthic macroinvertebrate communities. Hydrobiologia 518: 95–104.

Lara, R. 2006. Morfometría y biología reproductiva de *Macrobrachium carcinus* (Decapoda, Palaemonidae), Río San Carlos – Río San Juan, Costa Rica – Nicaragua. Tesis de licenciatura, Universidad de Costa Rica, San José, Costa Rica.

Laurance, S. G. W. 2004. Landscape connectivity and biological corridors. In Schroth, G., G. da Fonseca, C. Harvey, C. Gascon, H. L. Vasconcelos & A. M. N. Izac (eds.). Agroforestry and biodiversity conservation in tropical landscapes. Washington, DC: Island Press, 50-63.

Leenders, T. 2001. A Guide to Amphibians and Reptiles of Costa Rica. Miami: Zona Tropical.

Mc Dade, L., K. Bawa, H. Hespenheide & G. Hartshorn. 1994. La Selva: Ecology and Natural History of a Neotropical Rain Forest. Chicago: The University of Chicago Press.

Madriz, B. 2004. Relación de dependencia directa para la alimentación y anidación de la lapa verde (Ara ambigua) y el almendro (Dipteryx panamensis) en la zona norte de Costa Rica. San José, Costa Rica: SINAC, FONAFIFO.

Mata, R. 1991. Los Ordenes de suelos de Costa Rica. Taller de Erosión, Memoria. Heredia, Costa Rica: MADE, UNA.

Mata, A. & F. Quevedo. 2005. Diccionario didáctico de ecología. San José, Costa Rica: Editorial de la Universidad de Costa Rica.

MARENA. 2001. Vedas nacionales indefinidas, Nicaragua. Resolución ministerial 007-99. Managua, Nicaragua: MARENA, Proyecto Manejo Sostenible del Municipio El Castillo, Río San Juan / DANIDA, afiche.

Melton, B. 2009. In-stream gravel mining impacts and environmental degradation feedback associated with gravel mining on the Rio Tigre of the Osa Peninsula, Costa Rica, and the proposed ADI Jimenez Gravel Mining Concession. Austin, Texas: Melton Engineering Services.

Mena, Y. & G. Zamora. 1998.Parques nacionales y otras áreas silvestres protegidas de Costa Rica. San José, Costa Rica: MINAE-SINAC.

Monge, G., O. Chassot, R. Lopez & H. Chaves. 2002. Justificación biológica para la creación del propuesto Parque Nacional Maquenque. San José, Costa Rica: Centro Científico Tropical.

Monge, G., O. Chassot, G. Powell, S. Palminteri, U. Aleman & P. Wright. 2003. Ecología de la lapa verde (Ara ambigua) en Costa Rica.Zeledonia 7(2): 4-12.

Monge, G. & O. Chassot. 2005. Corredor Biológico San Juan-La Selva: trayectoria local, nacional, binacional, regional e internacional. In Rojas, L. & M. Chavarría (Eds.). Corredores biológicos de Costa Rica. San José, Costa Rica: Corredor Biológico Mesoamericano.

Moreno, T. & E. Müller. 2007. Formulario de Propuesta. Reserva de Biosfera Agua y Paz, Costa Rica. San José, Costa Rica: Universidad para la Cooperación Internacional.

Mol, J. & P.E. Ouboter. 2003. Downstream Effects of Erosion from Small-Scale Gold Mining on the Instream Habitat and Fish Community of a Small Neotropical Rainforest Stream. Conservation Biology 18:201–214.

MINAE. 2005. Reglamento a ley de conservación de la vida silvestre. Decreto 32633. La Gaceta No. 180. San José, Costa Rica: MINAE.

Packer, D.B., K. Griffin & K.E. Mc Glynn. 2005. A review of the effects of in- and near-stream gravel extraction on anadromous fishes and their habitats, with recommendations for avoidance, minimization and mitigation, NMFS-F/SPO-70.

Peterjohn, W. T. & D. L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of riparian forest. Ecology 65(5): 1466-1475.

Powell, P., P. Wright, U. Aleman, C. Guidon, S. Palminteri & R. Bjork. 1999. Resultados y recomendaciones para la conservación de la lapa verde (Ara ambigua) en Costa Rica. San José, Costa Rica: Centro Científico Tropical.

Pringle C. 2006. Hydrologic connectivity: a neglected dimensión of conservation biology. In Crooks, K. R. & M. Sanjayan (eds.). Connectivity conservation. Cambridge, UK: Cambridge University Press, 233-254.

Proyecto Río San Juan-Amigos de la Tierra. 2000. Plan de Manejo del Refugio Nacional de Vida Silvestre Corredor Biológico Fronterizo.Versión final sin publicar.

Quesada, F. & Q. Jiménez. 1997. Árboles de la Península de Osa. Heredia, Costa Rica: Instituto Nacional de Biodiversidad.

Quesada,M.R. 1997. Struktur und Dynamik eines tropischen Feuchtwaldes nach Holznutzung in Costa Rica. Dokt. Diss. Forstwiss. Fachbereicht, Universität Göttingen, Deutschland..

Rabeni, C., K. Doisy & L. Zweig. 2005. Stream invertebrate community functional responses to deposited sediment. Aquatic Sciences 67: 395-402.

Reid, F. 1997. A Field Guide to the Mammals of Central America and Southeast Mexico. Oxford: Oxford University Press.

Rojas, R. 2002. Estudio de base para la evaluación del impacto ambiental de un proyecto de minería de oro en Cerro Crucitas. Descripción de la ictiofauna. Apéndice 7.1. Estudio de impacto ambiental. Proyecto Minero Crucitas. Tomo IV. Apéndices 6.4 -8.5. San José, Costa Rica: Industrias Infinito, DEPPAT, Jacques Whitford Environments Limited.

Ryan, P.A. 1991: Environmental effects of sediment on New Zealand streams: a review. New Zealand Journal of Marine and Freshwater Research 25:207-221.

Salas, M. 2008. Aplicación de los lineamientos de la Convención Ramsar en la conservación de los humedales del Refugio Nacional de Vida Silvestre Mixto Maquenque. San Ramón, Costa Rica: Universidad de Costa Rica.

Salvatierra, T., R. Varela & L. Moreno. 2013. Macroinvertebrados acuáticos como indicadores biológicos de calidad. In T. Salvatierra (ed). Contribución al establecimiento de la línea de base ambiental del río San Juan de Nicaragua - 2012. Managua, Nicaragua: Centro para la Investigación en Recursos Acuáticos de Nicaragua, Universidad Nacional Autónoma de Nicaragua, 138 - 157.

Sánchez-Vindas, P. & L. Poveda. 1987. Claves dendrológicas para la identificación de los principales árboles y palmas de la zona norte y atlántica de Costa Rica. San José, Costa Rica: Overseas Development Administration.

Savage, J.M. 2002. The amphibians and reptiles of Costa Rica. A Herpetofauna between two continents, between two seas. London: The University of Chicago Press.

Springer, M. 2008. Biomonitoreo de la fauna de macroinvertebrados acuáticos en los cuerpos de agua en el área de la explotación minera Crucitas, San Carlos, Costa Rica. San José, Costa Rica: Laboratorio de Biomonitoreo Acuático, AquaBioLab, S.A.

Stiles, G., A. Skutch & D. Gardner. 1989. Guía de aves de Costa Rica. Heredia, Costa Rica: Instituto Nacional de Biodiversidad.

Stotz, D., J. Fitzpatrick, T. Parker & D. Moskovits. 1996. Neotropical Birds. Ecology and Conservation. Chicago & London: The University of Chicago Press.

Talley, D.M., G.R. Huxel& M. Holyoak. 2006. Connectivity at the land-water interface. In Crooks, K.R. & M. Sanjayan (eds.). Connectivity conservation. Cambridge, UK: Cambridge University Press, 97-129.

Tournon, J. & Bellon H., 2009. The southern Central America puzzle: cronology and structure. A review. Revista Geológica de América Central 32: 13-31.

UICN-Mesoamérica. 1999. Humedales de Mesoamérica, Sitios Ramsar de Centroamérica y México. San José, Costa Rica: Unión Mundial para la Naturaleza.

Vilhena, F., B. Finegan, S. Velásquez& B.C. França. 2004. Parámetros para la delimitación y manejo adaptativo de zonas de amortiguamiento en parques nacionales del Cerrado, Brasil. Recursos Naturales y Ambiente 41:16-24.

Villate, R., L. Canet, O.Chassot & G. Monge. 2008. El Corredor Biológico San Juan-La Selva: una estrategia exitosa de conservación. The Nature Conservancy, Centro Científico Tropical, CATIE.

Vreugdenhill, D., J. Meerman, A. Meyrat, L.D. Gómez& D.J. Graham. 2002. Map of the ecosystems of Central America: final report. Washington, DC: World Bank.

Wagenhoff, A., C. Townsend & C. Mattgaei. 2012. Macroinvertebrate responses along broad stressor gradients of deposited fine sediments and dissolved nutrients: a stream mesocosm experiment. Journal of Applied Ecology 49: 892–902.

Wood, P.J. & P.D. Armitage. 1997. Biological effects of fine sediment in the lotic environment. Environmental Management 21:203–217

World Bank, Comisión Centroamericana de Ambiente y Desarrollo (CCAD). 2001. Ecosystems of Central America (ArcView regional map files at 1:250,000). Washington, DC: World Bank, Comisión Centroamericana de Ambiente y Desarrollo (CCAD), World Institute for Conservation and Environment (WICE), Centro Agronómico Tropical de Investigación y Enseñanza (CATIE).

Zamora, N., Q. Jiménez & L. Poveda. 2000. Árboles de Costa Rica. Vol. II. Santo Domingo de Heredia, Costa Rica: Instituto Nacional de Biodiversidad, Centro Científico Tropical, Conservación Internacional.

9 ANNEXES

9.1 BioSketches of consultants participating in the realization of the EDA-Ecological Component

9.1.1 Geography and Land Use Planning Expert

Name	**Oscar Arturo Lücke Sánchez**
Profession	Forest Engineer
Date of Birth	15/05/1950
Nationality	Costa Rican
Residency	San José, Costa Rica
Telephone/Fax	2280-0270
Email	olucke@racsa.co.cr

Education

1982 Master of Forestry, Duke, North Carolina, USA

1978 Forest Engineer (Bachelor's), Costa Rican Institute of Technology. Cartago, Costa Rica

Professional Experience

Professor of land use planning in the University of Costa Rica's School of Geography. He has worked as a consultant for several Central American bodies since 1989, including: Central American Integration System (SICA); Regional Committee on Hydraulic Resources (CRRH); PNUD; BID; State of the Nation Project (CR); Central American Commission for Environment and Development; "Program for the Sustainable Development of the Central American Humid Tropics" (UICN)/ European Economic Community (CEE)/French Research and Technological Change Group (GRET). He also held the position of Regional Project Director of the "Strategic Actions to Strengthen the Policies for the Integrated Management of Central American Watersheds and Coastal Areas", which was funded by the OAS and executed by the SICA's Regional Committee on Hydraulic Resources. Former Regional Technical Assistant Director of the International Union for the Conservation of Nature (UICN-ARPA), Central America Regional Office, years 1992-93. From 1990 to 1991 he was a Fulbright Guest Lecturer in Clark University, Worcester, Massachusetts. He was also in charge of the "Management of Tropical and Subtropical Forest Ecosystems from Southern Mexico to Panama with CATIE/PNUMA" project in charge the Watershed Management Unit of the Costa Rican Water and Sanitation Institute.

9.1.2 Sustainable Tourism Expert

Name	**Ana L. Baez**
Profession	Biologist, Museologist
Date of Birth	04/03/1958
Nationality	Costa Rican
Residence	La Guácima, Alajuela, Costa Rica
Telephone	8837-3240
Email	turbaez@racsa.co.cr

Education

1980 Bachelor in Biology, University of Costa Rica. San Jose, Costa Rica.
1984 Licentiate Degree in Zoology, University of Costa Rica. San Jose, Costa Rica
1990 Master's Degree in Museology, Leicester University, United Kingdom

Professional Experience

President of the company *Turismo & Conservación Consultores S.A.*, Ana Baez works as an international consultant in areas such as the development, management, and strengthening of tourism; and sustainability, conservation, quality of life, museology, and management initiatives. Her areas of expertise include planning, developing, and assessing regional strategies, policies, plans, and products relating to private initiatives and protected areas; designing and managing sustainable development initiatives; designing tourism and visitor programs for protected areas; and applying guidelines and tourist certification standards for the management and operation of sustainable services. Her international clients include BID-FOMIN, AID, PNUD, PNUMA, USAID, GEF, TNC, WWF, FUNBIO, SEBRAE, AED, CREST, TIES, CBD, GSTC, UNWTO, Rainforest Alliance, and Tourism Institutes from Guatemala, Honduras, Nicaragua, Brazil, Bolivia, and the Dominican Republic, among others. In Costa Rica she works with the National System of Conservation Areas (SINAC) and the Costa Rican National Tourism Institute. Her past experiences include: Assistant Director of the Costa Rican National Museum, Dean of ULACIT's School of Tourism, and National Coordinator of the Regional Project *Paseo Pantera* ("Path of the Panther") Ecotourism Program. She has worked as researcher and contributor in projects such as Heritage Tourism in Central America (UNEP-Rainforest Alliance); monitoring systems for the public use of the National System of Conservation Areas in Cuba (PNUD-CNAP); training program for business owners that design sustainable tourism products (COTELCO-ANTIOQUIA); sustainable tourism development alternatives for community forest concessions within the Maya Biosphere Reserve, Petén, Guatemala (TIES); Mainstreaming Biodiversity Conservation into Tourism through the Development and Dissemination of Best Practices (UNEP-GEF); Sustainable Tourism Cluster as a Development Alternative for Latin-America and the Caribbean (BID-FOMIN); Nationwide Sustainable Tourism Strategy for Protected Conservation Areas (SINAC-ICT-BID); designing of sustainable tourism products (UCI); among others.

9.1.3 Biology and Management of Natural Resources Expert

Name	**Guisselle Monge Arias**
Profession	Biologist
Date of Birth	02/12/1970
Nationality	Costa Rican
Residence	Santa Ana, San José, Costa Rica
Telephone	8931-0947
Email	gmonge@cct.co.cr

Education

1996 Bachelor in Tropical Biology

2002 Licentiate Degree in Tropical Biology with an emphasis on Management of Natural Resources, National University. Heredia, Costa Rica

2010 Doctorate in Management of Natural Resources and Sustainable Development with an emphasis on Management of Natural Resources, Costa Rican Institute of Technology. Cartago, Costa Rica.

Professional Experience

Dr. Guisselle Monge currently works in the *Centro Científico Tropical* (Tropical Science Center) in Costa Rica, as Co-director of the Green Macaw Research and Conservation Program; Co-coordinator of the Local Council of the San Juan-La Selva Biological Corridor; Founding Member of the Mesoamerican Parrot Conservation Network; and Vice-president of the Mesoamerican Society for Conservation Biology, Costa Rican Chapter. Guisselle Monge has ample working knowledge in sustainability and a wide experience in designing projects, fundraising, and implementing conservation biology programs, biological corridors, leading inter-institutional alliances at national, binational, and regional levels, and in the creation of protected areas. She has worked as a researcher and collaborator in several projects, among which the following can be highlighted: ecology of the green macaw (*Ara ambiguus*); assessment of the conservation and population viability of the green macaw (*Ara ambiguus*) in the El Castillo-San Juan-La Selva, Costa Rica-Nicaragua Binational Biological Corridor; biological monitoring of *Ara ambiguus* nests in the northern area of Costa Rica; Management of the San Juan-La Selva Biological Corridor; biological justification for the proposed establishment of Maquenque National Park; involvement of nine strategic rural communities in the management, adoption, and reconstruction of the San Juan-La Selva Biological Corridor; Fact sheet for the El Castillo-San Juan-La Selva, Costa Rica-Nicaragua Binational Biological Corridor; Maquenque Mixed National Wildlife Refuge Management (MMNWR) Plan; Environmental assessment of the Maquenque MNWR; Sustainable and development principles application model for the monitoring of biological corridors; Landscape dynamics for the Northern Caribbean region of Costa Rica: implications for the conservation of the moist rainforest (*bosque tropical muy húmedo)*; establishment of a cross-border conservation and development area in the lower San Juan watershed.

9.1.4 Land Use Expert

Name	**Rafael A. Bolaños Montero**
Profession	Forest Engineer
Date of Birth	17/09/1956
Nationality	Costa Rican
Residency	Venecia, San Carlos, Costa Rica
Telephone	2472-1821
Email	rbolanos@cct.or.cr

Education

1978 Bachelor in Forest Engineering. Costa Rican Institute of Technology. Cartago, Costa Rica

1975 Agriculture and Livestock Expert. San Carlos Institute of Agriculture and Livestock. Alajuela.

Professional Experience

Former Director of Monteverde Cloud Forest Reserve; and former Coordinator and Administrative Assistant of the Network of Small Reserves (CCT). As a consultant he has worked in land use studies for private properties (INTA, MAG); ecology, forest coverage and land use studies for EIA of the following projects: Hydroelectric Project Don Carlos (Upala), Hydroelectric Project Chimurria (Upala), HYDROELECTRIC PROJECT Angostura (ICE); Northern Area of Costa Rica (DESFIL-USAID); HYDROELECTRIC PROJECT Toro (ICE); HYDROELECTRIC PROJECT Sandillal; HYDROELECTRIC PROJECT Arenal; HYDROELECTRIC PROJECT Boruca; Kuna Yala Reserve (Panama). Life Zones Expert in Costa Rican Life Zone Maps and Pichis Palcazu Valley Life Zones (Peru); Hawaii Islands, Papua New Guinea, San Juan River (Nicaragua); Bay Islands (Honduras); EIA Coordinator in lithic material concessions, Platanar river (San Carlos); creation of dry season maps of Costa Rica, 1:200.000 scale (CCT); Methodology and field survey consultant for the Ecosystem Map of Ecuador (in progress) (CCT-ESPEA); Coordinated the study to compensate the alterations caused to the Tambor (Cóbano) wetland; Environmental regent and Form D1 for the paving of a private road in Paquera (Puntarenas); biodiversity valuation under the PSA (Payment of Environmental Services in Spanish) program's economic valuation of Costa Rica (FONAFIFO-CCT); Mahogany diagnosis in Mesoamerica (CCT-PROARCA/CAPAS-IRG-USAID); Costa Rican forest coverage map (CCT-CIEDES-FONAFIFO); EIA HYDROELECTRIC PROJECT Pirrís land use expert (CCT-ICE).

9.1.5 Aquatic Biology Expert

Name	**Bernald Pacheco**
Profession	Biologist
Date of Birth	21/11/1978
Nationality	Costa Rican
Residence	San Pedro, San José, Costa Rica
Telephone	8992-2693
Email	bernald.pacheco@gmail.com

Education

1980	Bachelor in Biology, University of Costa Rica. San José, Costa Rica
1984	Licentiate Degree in Biology, University of Costa Rica, San José, Costa Rica
Present	Master's Degree in Project Management, University for International Cooperation. San José, Costa Rica

Professional Experience

Expert in aquatic entomology and bio-monitoring; he has specialized training in the following disciplines relating to aquatic ecosystems: Aquatic Entomology, Bio-monitoring of aquatic environments, Environmental Issues and Possible Solutions, Ecology of Aquatic Environments, Environmental Impact Assessment, Aquaculture, Aquatic Ecosystems: threats, risks, and conservation; Hydrothermal Vents, Geographic Information Systems, Ichthyology, and Herpetology. He currently works as Manager of AquaBioLab S.A.'s Bio-monitoring Laboratory, a company with which he has conducted various studies concerning aquatic fauna and limnology with regards to Environmental Impact Studies, Environmental Management Plans, bio-monitoring of hydroelectric projects, industrial and agricultural pollution, and mining, among others. He also works as an associate researcher for the Zoology Museum of the University of Costa Rica's School of Biology. He has taught aquatic bio-monitoring workshops for UCR's Integral Environmental Management Program; in addition, he has participated as guest lecturer on courses such as Tropical Biology and Tropical Field Ecology (USAP-OET, Kent State University) for the aquatic bio-monitoring sections. He has contributed as researcher and assistant in various projects, among which the following can be highlighted: Integral Management Project for Jabonal River's Watershed (PROGAI-UCR); "*Effects of irrigation canals on stream ecosystems in a tropical dry forest region of Costa Rica*" (Suzzane Moellendorf Doctoral Dissertation-University of Florida); "*Hymenopteran parasitoids associated with rice crops in Costa Rica*" (UCR-Dr. Paul Hanson). Furthermore, he has presided over aquatic entomology conferences (University of Costa Rica, XIIIth Congress of Mesoamerican Society: Biology and Conservation-Belize, IIIrd Colombian Congress of Zoology-Colombia); and has published several papers on aquatic entomology.

9.1.6 Geographic Information Systems Expert

Name	**Andreas Mende**
Profession	Geologist
Date of Birth	14/12/1966
Nationality	German
Residence	San José, Costa Rica
Telephone/Fax	2292-8785
Email	amende@racsa.co.cr

Education

1995 Geology Degree, University of Bonn and University of Cologne, Germany
1999 Doctorate in National Sciences, Stuttgart University, Federal Republic of Germany

Professional Experience

Ever since 2005 he has worked as a consultant for *Geo-Resiliencia S.A.* in the fields of Geographic Information Systems (GIS), environmental geology, natural disaster prevention, hydrogeology, and geotechnics. He has additionally participated as a researcher and scientific contributor in several projects, including: "Land Suitability Mapping" (UCR/German Research Foundation – DFG); TICOSECT (German Research Foundation – DFG/ University of Stuttgart, Germany); Archeological Field Survey (Archeological Service/University of Cologne, Germany). Other projects of his include: Digital Atlas for the United Nations' "Integrating Watershed and Coastal Areas Management in Caribbean Small Island Developing States" program; "Natural Disaster Risk Analysis for Costa Rican Communities" for the National Commission for Risk Prevention and Emergency Management (CNE); Territory Ordering in the Maritime and Terrestrial Zone of the provinces of Guanacaste and Puntarenas (EPYPSA S.A.); Environmental Characterization for the Development of Marinas and Piers in the Costa Rican Pacific Coast; Environmental Zoning and Territorial Base Study-PRUGAM (INDECA-Astorga); Zoning Proposal based on the Environmental Fragility Indices for the Municipality of Escazu's Zoning Plan (Geo-Resiliencia S.A.); Geological-Environmental Analysis of Jabonal river's subwatershed (progai-ucr); Land Suitability and Environmental Fragility Assessment of Orosi and the creation of Guidelines for Land Use (CNE); Geological-Geomorphological Study for Drake Bay's Zoning Plan (Geo-Resiliencia S.A.).

9.1.7 Connectivity Expert

Name	**Olivier Chassot Labastrou**
Profession	Gestión de Recursos Naturales
Date of Birth	17/09/1972
Nationality	Suizo-Costarricense
Residency	Santa Ana, San José, Costa Rica
Telephone	8822-0226
Email	ochassot@cct.or.cr

Education

1997 Bachelor´s in Arts, History, Old History, Language and French Literature, Université de Lausanne. Switzerland

2005 Masters in Project Management, University for International Cooperation. San José, Costa Rica

2010 Doctorate in Natural Sciences for Sustainable Development, Costa Rican Institute of Technology. Cartago, Costa Rica

Professional Experience

Executive Director at the Tropical Science Center (Costa Rica), Co-Director of the Great Green Macaw Research and Conservation Project, Co-Coordinator of the Executive Committee of the San Juan-La Selva Biological Corridor, Chairman of the Foundation for Participatory Environmental Management, Coordinator of the Mesoamerican Parrot Conservation Network, Chairman of the Mesoamerican Society for Conservation Biology, Deputy Vice-Chair for Connectivity Conservation at the Mountains Biome of the World Commission on Protected Areas (WCPA-IUCN), Vice-Chair for Mesoamerica at the Transboundary Specialist Group of the World Commission on Protected Areas (WCPA-IUCN), Coordinator of the International Connectivity Conservation Network (WCPA-IUCN), Director of Communications for the Austral and Neotropical America Section of the Society for Conservation Biology (SCB), and is also an active member of the World Commission on Ecosystem Management (CEM-IUCN). He has been the Director of Science at the Tropical Science Center, Dean of Environment and Sustainable Development and Director of the Latin American School for Protected Areas (ELAP) at the University for International Cooperation (UCI) in Costa Rica, from 2009 to 2010. Dr. Chassot has an extensive knowledge in sustainability topics, and experience in designing, fundraising and implementing conservation biology programs, biological corridors, leadership of inter-institutional alliances at the national, bi-national and regional level, as well as in the creation of protected areas. Author of 102 publications and 123 presentations at international conferences and workshops (Costa Rica, Nicaragua, El Salvador, France, Germany, Ecuador, Peru, Belize, Puerto Rico, Brazil, Honduras, Panama, Spain, Mexico, Guatemala, the United States, Colombia, Korea, Cuba, Switzerland, New Zealand, Australia, Chile and Monaco). Coordinator of 70 national and regional events (Costa Rica, Nicaragua, El Salvador, Honduras, Guatemala, Cuba, Mexico, Brazil, Panama, South Korea and Belize).

9.2 Impact assessment of the implementation of the Route 1856 project on the development of tourism activities in the San Juan River

Environmental Diagnostic Assessment

Ecological Component

Project Route 1856

"Juan Mora Porras"

Impact Assessment of the Implementation of the Route 1856 Project on the Development of Tourism Activities in the San Juan River

CENTRO CIENTIFICO TROPICAL

November, 2013.

Elaborated by:

Ana L. Baéz

Environmental Diagnosis Assessment

Route 1856 Project – Ecological Component

Impact Assessment of the Implementation of the Route 1856 Project on the Development of Tourism Activities in the San Juan River

By :

Ana L. Báez.

(Planning and Visitor Management in Natural and Cultural Areas Specialist

- Sustainable Tourism Management)

San José, Costa Rica.
November, 2013.

TABLE OF CONTENTS

1 INTRODUCTION 6
1.1 Background 6
1.2 Objectives 6
1.2.1 Especific Objectives 6
1.3 Methodology 6
2 GENERAL DESCRIPTION OF THE STUDY AREA 8
2.1 Socio-Economic Summary 8
2.2 Tourism Circulation 9
2.3 Tourist Profile 10
2.4 Services and activities 10
2.5 Tourism routes 12
2.5.1 Specialized observation of nature 13
2.5.2 Biosphere Reserves scientific tourism 13
2.5.3 Adventure tourism 13
2.5.4 Cultural tourism 13
3 LANDSCAPE CHANGE AND ASSESSMENT 14
3.1 Conservation efforts 15
3.1.1 The Biological Border Corridor is a declared Wildlife Refuge. 15
3.2 Landscape approach 16
4 RESULTS 17
4.1 On the diagnosis 17
4.2 On the route constructed 19
5 RECOMMENDATIONS 20
6 BIBLIOGRAPHY 21
7 APPENDIX 22
7.1 Summary of companies and institutions consulted by phone call of personal communication. 22
7.2 Itineraries for public transportation services in the department of Rio San Juan 22

i. Chart Index

Chart 1: Tourist arrivals to Nicaragua according to travel means and entry point (Serie 2008-2012). 9

Chart 2: Destination Classification according to PNDTS 2011-2020. 11

i. Map Index

Map 1: Tourism routes in the South of Nicaragua. 13

ii. Photograph Index

Photograph 1: Reforested areas along the Route. 17

iii. Glossary

Abiotic: designation for that which is not biotic, that is not a part of or a product of living organisms.

Tourism attraction: Any point or element of the natural or cultural patrimony of a site that is capable of motivating a visit by a tourist

Biodiversity: the variety of genetic material found in the flora and fauna of a locality.

Biotic: that which is characteristic of living organisms or that maintains a link to them

Local communities: communities that are adjacent to, or near, wildlife areas

Contamination: the addition of any natural or artificial matter to the air, water or ground in quantities such as to turn the resource inadequate for a specific use

Destination: geographic zone or area located in a distant place which is visited by a tourist, with limits that are physical, of political context, and of perception from the perspective of the marketplace. From a business perspective, organizational as well as strategic, the perimeter of a destination is constituted by the relationships that are built among the group of productive units that participate in the tourism activity.

Geographic Space: concept used by science to define spaces organized by society.

Excursion: a series of integrated services under a fixed itinerary which includes a number of places to visit (cities, sites).

Fam tours/ familiarization visits: (in English: “fam” tours), courtesy visits offered to journalists, tour operators and travel agencies so that they can experience first hand a visit to a destination so as to gain a better understanding of the product and a closer relationship, leading to improved future commercialization.

Tourism Industry: or Travel Industry, set of businesses dedicated to offering services related to travel which includes transport personnel, hotel staff and travel agencies of different types (wholesalers, retailers, tour operators, local operators).

Infrastructure: a set of elements or services that are considered necessary for an organization to function properly or for an activity to evolve effectively.

Tour Operator: An enterprise that creates and sells trips with all services included, or offers tourism services to be sold through other agencies in addition to selling directly to the public.

Tourism Package: a set of two or more tourism services that can be bought by and individual or group (regardless of number) and which normally includes lodging and a combination of other elements such as transportation, meals, local visits, etc.

Tourism Product: a set of material and immaterial services offered in the market with the aim of satisfying tourists´ desires and expectations.

Tourism: activities performed by individuals during their trips and visits to places that are not their habitual living place, for a continuous period of no more than a year and longer than one day, for purposes of recreation, business or other motives (OMT).

Sustainable Tourism: the type of tourism that is fully aware of the present and future economic, social and environmental repercussions of the fulfilment of their needs, the needs of industry, of the surrounding and host communities (OMT)

Tourist: visitor (internal, receptor o sender) who classifies as tourist (or visitor who stays overnight) if the trip includes an overnight stay.

Tourism Route: travel extension designed for the tourist to visit designated areas of tourism interest, or specific tourism attraction sites.

1 INTRODUCTION

1.1 Background

As part of an environmental analysis initiative related to the construction of the road known as Route 1856 (the Route, in this study), the services of the Tropical Science Center (TSC) were commissioned based on the organization´s well known prestige, experience and technical knowledge on environmental assessment topics, to conduct and Environmental Diagnostic Assessment (EDA) with emphasis on the Ecological Component. Closely related to this component, an assessment of impacts of the construction and operation of the road on the development of tourism activities in the San Juan River was included along with the EDA. The tourism study was directed by consultant Ana L. Báez.

Regarding the subject of tourism, the following precepts are to be determined:

1. If there is a technical basis to determine that the construction of Route 1856 adversely affects tourism on the San Juan River.
2. Goal: to investigate whether Route 1856 generates important visual and aesthetic impacts to tourism on the San Juan River.

1.2 Objectives

To justify the existence of potential impacts that might affect landscape value and the future development of ecotourism in the neighbouring areas due to the construction of Route 1856 on the right margin of the San Juan River (Costa Rica territory) based on technical criteria.

1.2.1 Especific Objectives

1. To describe the current and potential tourism development in the San Juan River.
2. To research potential aesthetic and visual impacts of Route 1856 on the potential for tourism development in the region of the San Juan River.

1.3 Methodology

The work conducted was based on three basic information collection methods:

- Bibliographic analysis.
- Interviews with key informants, commercial organizations and institutions.
- Fieldwork in the project area.

The specialist in charge of this project visited the study area on July 27, travelling from Tiricias to Delta Costa Rica, as a tourist on board a private small boat in order to gain a tourist perspective of the landscape, and to observe affected sites and initiatives that are underway in reforestation and protection of slopes along the Route.

Furthermore, on August 18, 2013 an observation flight was performed over the road construction area, flying in both directions and obtaining an excellent perspective of the route traced for the road.

The specific information on tourism activity, systematized offer and history of the development of services, and growth or decrease in visitation, is very limited and based on very different sources of information which are not consistent among them.

It was not possible to conduct a survey in the area, therefore direct telephone interviews were conducted with some of the main actors on both sides of the river; information that is presented in Annex 1.

Additionally, the study was complemented in a very productive way with periodic review processes and discussions with specialists in the team in charge of the EDA, and this offered a global view of the problems under study.

2 GENERAL DESCRIPTION OF THE STUDY AREA

2.1 Socio-Economic Summary

Conditions in the region of the study are generously described in the document "National Plan for the Development of Sustainable Tourism (PNDTS), San Juan River Destination, Development Strategy 2011-2020" INTUR-BID-AECID, which provides the following information. The San Juan River belongs to a political-geographical division known as Department of Rio San Juan, reported as the third poorest of such divisions in the country: 55% of the population in this department lives in conditions of extreme poverty. The department has 190,353 residents (2010). The capital of the department is the town of San Carlos, with a population of 42,358 inhabitants in 2010 (estimated by INIDE).

The percentage of houses with electrical services is 30.1%, which decreases to 12.4% in rural areas. Thrash disposal in 75% of homes is done by burning the thrash or placing it in empty lots, and only 1.4 of homes have potable water services.

The service of telephone communications, by cable or cellular, offers very low coverage. The cell phone company Claro offers their services in the town of San Carlos, while in other municipalities of the department the only communication option is by satellite, or, in some places by using cellular nets based in Costa Rica. San Juan in Nicaragua has cell phone and internet services.

Terrestrial transportation from Managua makes use of the new Managua-San Carlos highway, with an approximate length of 300 km lasting 4.5 hours. A proposed bridge over the San Juan River would without a doubt improve access to this destination, especially for tourism flows from Costa Rica.

The PNDTS considers this new highway as a means "that would allow proposing with a relatively short time (3 to 5 years) not only an increase in tourism to the San Juan river but also the development of tourism circuits of a bi-national type around Lake Cocibolca (Lake Nicaragua) or down the San Juan river all the way to San Juan del Norte and be able to connect with the Costa Rican coast". According to Costa Rican businessmen, that would only diminish travel by boat and it would provide benefits only when relations between the two countries are normalized and the region becomes safer.

Regarding fluvial transportation, the company Empresa Portuaria Nacional provides a service that runs between Granada and San Carlos, lasting 14 to 16 hours, using boats that are low on the scale of tourist expectations. From that point it is possible to take medium and large boats that travel on the San Juan River.

Collective transportation vessels are visibly deteriorated and do not offer comfortable conditions for a travel route that is longer than 2 hours to El Castillo and 13 hours to San Juan de Nicaragua. Nevertheless, there are private boats that offer better conditions, but at very high cost, estimated at up to $1,000 US dollars.

Concerning aerial transportation, the airline La Costeña covers the distance Managua to San Carlos. In early 2011 the company Nicawings offers hydroplane transportation from Managua and Granada to San Juan de Nicaragua. Details of all these services are included in Annex 2.

2.2 Tourism Circulation

Despite the fact that tourism development in Nicaragua has reported a sustained increase of 9% during the last decade[1], such growth does not reflect on tourism activities in the study area. Its main impact is still slow in San Carlos, El Castillo and San Juan de Nicaragua (see Chart 1).

The more recent visitation and point of entry information for control points in the study area indicate that entry at San Carlos totalled 13,464 tourists, an increase of 18% over the previous year. This is contrary to information from other sites such as San Juan del Sur, Sarapiquí (in Costa Rica), San Juan del Norte, and Papaturro, which show consecutive decreases between 2008 and 2011, with an increase of 5% in 2012, as summarized in the following chart (statistical bulletin: Boletín Estadístico de Turismo, 2012. Instituto de Turismo de Nicaragua).

It is worth noting that entrance through the different fluvial entry points in Nicaragua has suffered significant decreases during these years, starting with 25,502 in 2008 down to 16,574 in 2012.

Chart 1: Tourist arrivals to Nicaragua according to travel means and entry point (Serie 2008-2012)[2].

Aquatic entry point and post	*2008*	*2009*	*2010*	*2011*	*2012*
Potosí	917	862	814	855	693
Corinto	6,632	8,832	2,094	776	513
Puerto Sandino	83	22	1	83	17
Puerto Cabezas	18	8	0	140	0
Bluefields	373	251	190	136	254
San Carlos	*8,952*	*8,942*	*8,608*	*11,213*	*13,464*
Other posts 1/	*8,527*	*6,974*	*2,731*	*1,564*	*1,633*
Total tourists	857,901	931,904	1011,251	1060,031	1179,581

1/ Relates to tourists arriving to Nicaragua via San Juan del Sur, Sarapiquí, el Castillo, San Juan del Norte y Papaturro. Source: INTUR with data from Dirección General de Migración y Extranjería.

Studies conducted for the PDTS Strategy of the San Juan river, 2011-2020 report a tourism flow in the San Juan estimated at an average of 10,000 international tourists, about which the study concludes that “this is a very limited number that does not help the emergence and consolidation of a minimally viable tourism sector in the whole complex (which does not impede the existence of individual initiatives and businesses that are perfectly viable, as is in fact happening), and makes tourism a secondary activity, incapable of leading the economy of the department and acting as a motor in the social and economic development of the region”.

The image of San Juan River outside of the region is still undefined and very weak, despite the fact that it is a tourism destination that focuses mainly international tourists.

[1] Boletín Estadístico, 2012 http://www.intur.gob.ni/index.php?option=com_content&view=article&id=27&Itemid=14

[2] IDEM

2.3 Tourist Profile

Available studies that offer data on tourism in the region of the study are very few and non-systematic. The main and most recent source is the information prepared for the PNDTS/PDTS Strategy for the San Juan River, 2011.2020, based mainly on reports of the Araucaria Project XXI (AECID) which focuses attention on El Castillo and other neighbouring zones.

It is important to note that data correspond to year 2010, prior to the period of conflict that developed after the construction of Route 1856. Following is the typology cited for tourists who visit El Castillo and other areas neighbouring San Juan, Nicaragua [3]

a) International tourist (61.4%): Spain, Germany, France and United Kingdom are 31% and the United States 14%. Entry: 20% of tourists arrive through Costa Rica. Nicaraguans average between 7 and 12%.

b) Many tourists combine their visit to San Juan with other national destinations, mainly Granada, Leon, Managua and Masaya.

c) Arrival is strongly seasonal, with an absolute maximum occurring in the month of august.

d) Short stays are prevalent (the number of overnight stays is between 1,7 and 1,9 nights).

e) Age: 65% of tourists are aged 26 to 45 years.

f) The average daily expenses are around $ 53 US dollars.

g) Tourists generally travel with a group of friends and in second place in family groups (they prepare their own travel plans).

h) The main source of information are the tour guides (40,4%), followed by recommendations of friends and family (34,8%).

i) INTUR assumes that in 2010 a total of 12,100 tourists visited San Juan River (3,032 visited El Castillo), but due to the lack of consistent data this study offers an estimate of 10,000 persons who visited San Juan including national visitors.

j) During the first semester of 2010, 1,2% of tourists who visited Nicaragua reported having visited the San Juan River, 0,7% visited San Carlos and 0,3% visited El Castillo.

2.4 Services and activities

The variety and richness of tourism opportunities in the San Juan river region are based on the exuberant biodiversity present, the existence of large protected areas such as the Guatuso Refuge and Indio-Maiz Reserve, as well as the great extension of water that nourishes these resources.

Remoteness of the region and access that is mainly through fluvial means both cause this region to achieve a modest level in tourism development. To date this destination is assigned the following characteristics according to PNDTS 2011-2020, which also views this region as the highest development priority:

[3] Plan de Desarrollo Turístico Sostenible de Nicaragua. Destino río San Juan. Estrategia de desarrollo. 2011-2020 BID-INTUR-AECID.

Chart 2: Destination Classification according to PNDTS 2011-2020.

Destination	Main attractions	Main products	Priority[4]
San Juan River	1. Nature 2. Adventure 3. History	1. Nature observation 2. Adventure tourism 3. Cultural tourismo 4. Transit	1

The 50% of the services in the region are concentrated in the town of San Carlos and tourism activity is only 3,54% of that for the whole country. San Carlos acts as a distribution center for interest areas such as the Solentiname Islands, Lake Cocibolca, El Castillo and San Juan Norte. Communication among these locations is through fluvial means, which restricts travel mainly to established itineraries for public transportation services.

Infrastructure at this destination is very basic and limited, therefore important public and private investment is required in order to mature and progress as a tourism destination with a nature avocation. A total of 40 visitor boarding places are reported with 321 rooms and 616 beds available.

Only a few of these boarding places offer conditions for the type of product that is intended to be offered. In fact, hotels that are reported in the website www.riosanjuancanatur.org are the hotels Montecristo, Mancarron, Sábalo, Sábalo Lodge, Gran Lago, Victoria and Esquina del Lago.

Following are the tourism products that are offered in the web pages of the main establishments in the area:

1. **Travel by boat/nature observations:** this is one of the more common programs which includes short boat or kayak rides, as well as longer stretches that include the almost 300 km. to San Juan del Norte. In the proximity are found important channels and water surfaces that offer extraordinary visiting experiences.
2. **Walks:** in neighbouring areas or in planned routes with guides from the Indio Maiz Reserve or the Guatuso Refuge.
3. **Sports Fishing:** Royal Tarpon (Sábalo), Róbalo, Guapote. Gaspar and Machaca. Fishing is done by trolling and casting, normally with Rapala flies. Fishing areas are: Mouth of the Sábalo River, Poco Sol, Santa Cruz, El Castillo, Medio Queso, Santa Fe and El Pitazo rivers and lagoons. If the fishing is poor in the area clients can ask for a fishing tour in the Solentiname Islands where they can cast for Guapote and Laguneros fish.
4. **Rest:** the landscape offers excellent views and the tranquillity of the site permits contemplation and enjoyment of nature.

[4] Taken from Plan de Desarrollo Turístico Sostenible de Nicaragua. Destino Río San Juan. Estrategia de desarrollo. 2011-2020 BID-INTUR-AECID.

5. **Culture:** the offer includes crafts, cultural activities and the daily life patterns and practices of the multi-cultural groups present in the region.

2.5 Tourism routes

The development of tourism in Nicaragua points to a consolidation process of tourism routes as a strategy of differentiation and strengthening of destinations. In the case of San Juan River there are tourism proposals dating back before 2006 that include bi-national initiatives that joined efforts between Costa Rica and Nicaragua.

The governments of Costa Rica and Nicaragua worked jointly on the initiatives for the Water Route (Southeastern Nicaragua-Northeastern Costa Rica) based on natural attractions in rivers and channels, adding the interesting cultural and historical traditions of local populations. Likewise, the Nautical Route was a bi-national initiative based on nautical tourism in the Caribbean region that offered the best option to bring together tourism from Nicaragua, Costa Rica and Panamá.

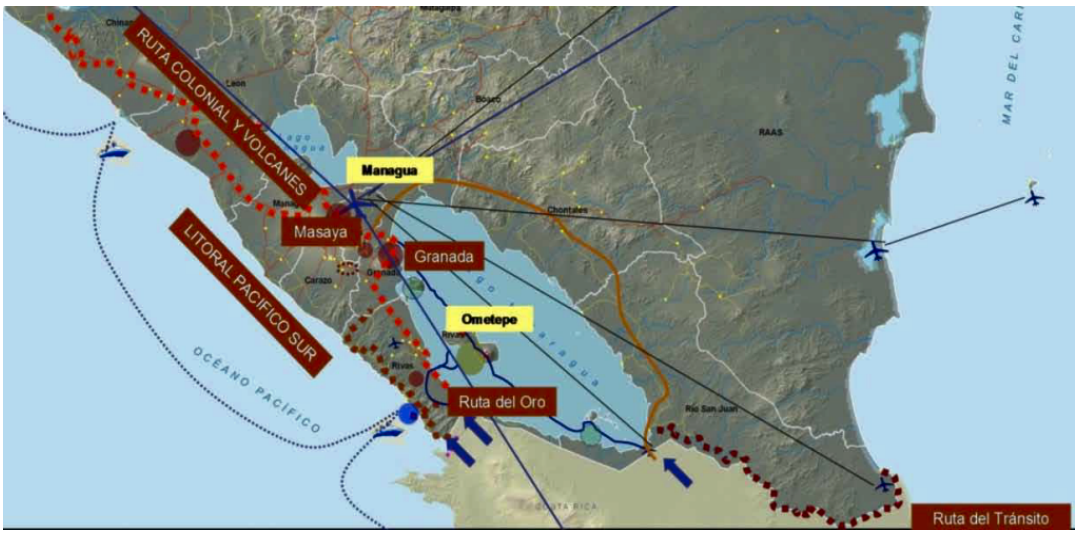
Sports fishing activities, mainly of sail fish and related, along with sailing and cruisers visitation, would permit diversification of natural products, sun and beach, adding value to natural products and allowing attraction of new markets based on the developing tourism port cities along the Caribbean coasts of Central America[5]. Neither of the previously mentioned initiatives has been able to move forward primarily due to the political instability in the San Juan River which has effectively dampened all joint developments.

Nevertheless, according to PNDTS 2011-2020, Nicaragua salvages the idea and various priority routes are identified for the region such as the consolidation of the San Juan River route also known as the Water Route (Transit Route) and the evaluation of the future Gold Route which stretches from San Juan del Norte to Greytown, on the Atlantic coast, all the way to San Juan del Sur on the Pacific side.

Growth projections for such destination are based mainly on the implementation of such routes as were identified as projects for the development of the region but which, up to the present, have not been implemented in their totality. This destinations are mentioned in PNDTS 2011-2020 as “these destinations with medium priority, with the appropriate improvement in infrastructure, services and conditions of the local populations, and the valuing of their resources, can become in the medium term big attractions for the holiday travel international markets, being as they already are, in large measure, tourism destinations for national and regional tourists.”

[5] Comisión Regional de Iniciativa Mesoamericana de Turismo. Perfil de Proyecto. Ruta del Caribe Centroamericano

Map 1: Tourism routes in the South of Nicaragua.



Taken from: PNDTS (2011-2020).

The PNDTS proposes 4 main market segments to concentrate activities and potential offers for this destination:

2.5.1 Specialized observation of nature

The Water Route, which runs down the San Juan River and has natural and landscape resources, allows visitation of the Indio-Maiz Biosphere Reserve and Los Guatusos Refuge for observation of flora and fauna, birds and manatees. The Lake Cocibolca coast and Islands provide a unique combination of landscapes and volcanoes, archipelagos and islands.

2.5.2 Biosphere Reserves scientific tourism

Bosawás is the largest and best preserved tropical forest in Central America and it includes natural reservations such as Cerro Banacruz, Cerro Kilambé, Macizo Peñas Blancas and the Cerro Saslaya National Park. The San Juan River destination includes the Indio-Maíz Biological Reserve, the Los Guatusos Wildlife Refuge, the San Juan River Wildlife Refuge and the nature reserves of Cerro Silva and Punta Gorda.

2.5.3 Adventure tourism

The Water Route facilitates access to the Indio Maiz Reserve, the Solentiname Archipelago, and the Guatusos Refuge, allowing for adventure and recreational tourism.

2.5.4 Cultural tourism

Cultural tourism in the San Juan region can be based on the Water Route destination, the Lake Cocibolca communities and Granada, all of which constitute the historical scenario of colonial development in Nicaragua and the pirate incursions which gave rise to fortresses, etc.

The Gold Route stretches beyond the San Juan river across the Rivas isthmus and to San Juan del Sur provides an historical account of the gold rush to California using the San Juan River as a transit route, and the arrival of the filibuster troops in Nicaragua.

3 LANDSCAPE CHANGE AND ASSESSMENT

The landscape is defined as an area that can be observed from a site and that involves an observer and an observed object whose outstanding features are the visual and spatial qualities.

In general, landscape is understood to be a terrestrial surface area resulting from the interaction of the different factors present in it and which have a visual reflection in space. The geographic space is defined by the forms, natural or anthropic that compose it. All landscapes are formed by elements that are articulated among them. These elements are essentially of three types: abiotic (non-living), biotic (resulting from the activities of living organisms) and anthropic (resulting from human activity)[6].

There are multiple methods for the assessment and valuation of landscape, according to interest, function and discipline from which the analysis is done. In our case we consider the landscape of the study area as a representative sample of the conditions existing before and after Route 1856 came into existence, on the margin of San Juan river in the stretch that covers from Landmark 2 to Delta Costa Rica, with the main purpose of this analysis being the possible alterations that such landscape might have suffered due to the intervention and the creation of the terrestrial access route.

The territorial unit of study in its original conditions was constituted by extensive areas of tropical forest mixed with wetland systems [7] in addition to a large number of tributaries of San Juan River including two important rivers, the San Carlos River and the Sarapiquí River, which contribute significantly to the dynamics of the study area.

The study area was already an anthropic landscape with agricultural and cattle-raising activities present for more than a century and with some stretches of roads that represent a large percentage of the landscape before the intervention of Route 1856.

Route 1856 takes advantage of the many roads existing in the region to interconnect with the main road and facilitate communication among some of the towns and hamlets along the route designed. An example is that of the 108.2 km. that make up the route under study, 46.2 % (52 km.) already existed before the road construction.

The presence of communities and small hamlets along the road in the study area is evidence of a clear and marked human presence associated to agricultural and cattle-raising activities that dates over one century. The different modifications in the use of land due to human presence constitute a landscape of a mosaic type, integrated by pastures, agricultural production, live fences, forest patches, which in many cases blend with important extensions of tropical forests. The set of these resources and activities results in a mixed, dynamic landscape which is proper in rural areas of Costa Rica.

[6] Source: Wikipedia
[7] For technical details, see “Terrestrial Ecological Environment” in EDA- Ecological Component Report.

3.1 Conservation efforts

3.1.1 The Biological Border Corridor is a declared Wildlife Refuge.

The Route 1856 is part of the Nicaragua-Costa Rica Biological Border Corridor National Wildlife Refuge. Arrieta (2013) summarizes the conservation status of the area of this study, thus:

It is important to point out that despite its condition as Wildlife Refuge, the Border Corridor has been characterized by the presence of inhabitants and settlements in its area who are afflicted by poverty, a condition that led the government to declare it: "Declaration of Public Interest by the Inter-institutional Commission of the National Wildlife Refuge Biological Border Corridor and All Other Northern Territories" all in accordance with Decree No. 35849-MINAET.

On the other hand, the Maquenque Mixed Wildlife Refuge was created by Executive Degree No. 32405-MINAE of 23 May 2005, with an extension of 51,855 hectares and which incorporates under this new management category the following: Forest Reserve Cerro El Jardin, (Executive Decree 22990-MIRENEM), Forest Reserva La Cureña (23074-MIRENEM) the Wetland Lagoon Tamborcito (22965-MIRENEM) and the Laguna Maquenque Palustrine Wetland (22964-MIRENEM).

The Executive Office justified the decision to create such Refuge with the following:

> *"Given its scientific interest, this is an area considered of importance for conservation since it presents special characteristics for the conservation of important species of flora and fauna, among them: the green parrot (Ara ambigua), the Jaguar (Panthera onca), the Almendro tree (Dypterix panamensis), the Manatee (Trichechus manatus), the Gaspar fish (Atractosteus tropicus) and the Pinillo tree (Podocarpus guatemalensis). The geographic location of this area is of great importance since this protected wildlife area would be located within the Bi-national El Castillo-San Juan-La Selva Biological Corridor, which is a continuation of the Mesoamerican Biological Corridor between Nicaragua and Costa Rica and which constitutes the last significant block of natural forest cover that maintains biological connectivity between the two countries, so that this area would connect key habitats and wildlife corridors, preventing the isolation of species and native ecosystems."*[8]

The TSC considers this as "the central conservation unit of the San Juan-La Selva Biological Corridor" since it is located south of the Indio-Maiz Biological Reserve and lies on the western limit of the National Wildlife Refuge Barra del Colorado. It is particularly relevant because of humid tropical forest extensions and for being the ecosystem of the green parrot (Ara ambigua).

With respect to the construction of a pathway or road in this protected area, the Executive Decree No. 32405-MINAE indicates that "even though it is not usual to build new pathways within a conservation area such as a wildlife refuge, it is not prohibited, since such construction may be necessary to better achieve the assigned conservation goals; to better fend off eventual hunters and collectors of biodiversity samples, among other."

It is appropriate to note that from the perspective of the San Juan River margin on the Nicaraguan side, there are important conservation efforts taking place and presently there exist the Los Guatusos Refuge, the Indio-Maíz Biological Reserve, which is part of the Mesoamerican Biological Corridor.

[8] Executive Decree No. 32495, article 7.

According to Martínez-Sanchez (2001) a strip of land of 10 km wide was cut off the Indio-Maiz Reserve, on the Nicaraguan margin along the length of the San Juan River, to allow tourism development and other recreation activities along the river and the coastal area. For this purpose, this area of the Indio-Míiz Reserve was re-classified to the category of Wildlife Refuge, a conservation category with in Nicaragua is more permissive than that of Reserve.

The previous change was done in order to permit the establishment of hotel complexes along the San Juan River and on the Caribbean coast. Nevertheless, the dominant landscape continues to be the forest in different states and no infrastructural development, facilities or other tourism developments are evident except for very isolated houses and the vigilance and migratory posts.

3.2 Landscape approach

On the topic of the alterations created on the landscape by Route 1856 that might affect tourism development in Nicaragua as presented, the study contemplated landscape sets from the perspective obtained from the San Juan River, currently a place of very sporadic transit by visitors or tourists, as well as from an aerial perspective. This leads to some considerations:

a. The anthropic landscape of the territorial unit under study contains the elements that correspond to a rural Costa Rican landscape, altered by a series of elements such as pastures, agriculture, housing areas and animal husbandry areas, live fences, interconnected forest patches and, in some cases, a creek or river that provides a boundary.

b. The rural landscape changes as important patches of forest appear which in most cases are part of the public-private units under protection and that, under different management categories, assure the presence of forests in the region.

c. In the study area, alteration of terrain due to the establishment of a part of the Route is recent and made evident by the formation of very particular geological zones of reddish clay soils common in local substrate which contrast with the series of multiple shades of green that dominate the landscape.

d. There are points of reference and visibility in the Route related to areas where the road had to be built on terrains having the most inclined slopes and where it is possible to see landslides due to the cuts made on the hills.

e. Most slopes were discontinuously observed in the section between Marker 2 and the mouth of the San Carlos river. This is not very significant in terms of the general areas where there is alteration of the site. The remaining stretches that show some form of alteration are of little visibility from the river where eventually tourists would be travelling.

f. The bridge system does not exist and the installed services are temporary, some of them being collapsed, so that jointly they do not contribute to consolidate a landscape, and to some extent they limit the fluid travel along the Route, a situation that until it is improved will stop all other forms of development that might lead to changes in the region´s typical landscape.

g. A number of efforts are being conducted to recover plant vegetation along the Route through a reforestation program coordinated by CODEFORSA[9], which reports the

[9] CODEFORSA. Consultoría para el Desarrollo e Implementación de un Plan de Gestión Ambiental en el Camino Fronterizo Juan Rafael Mora Porras. SINAC-CDE-004-2012. Enero, 2013

planting of 27,000 trees in affected areas between Tiricias, Las Chorreras and the mouth of the San Carlos River, with an estimated 98% of trees located between the road and the margin of the San Juan River. Short term plans include planting and additional 25,000 trees before the construction of the Route 1856.

Photograph 1: Reforested areas along the Route.

4 RESULTS

4.1 On the diagnosis

1. The study area specifically does not offer conditions for tourism development, nor has it ever been an area of tourism development. To date, the stretch between Border Landmark 2 and Delta Costa Rica does not have any kind of tourism facility neither on the right nor on the left margin of the San Juan River. The only site where there are services and facilities is Delta Cabins, and these are mostly for national visitors. Towards the two extreme areas of the river, infrastructure and facilities improve, concentrating in the towns of San Carlos and San Juan del Norte.
2. It is important to note that tourism axes have concentrated in the endpoints of the river. In the case of Nicaragua, it offers services in San Carlos and neighbouring areas, and in Greytown, San Juan and its proximities. The remainder of the river, mainly the margin under study, has no services other than fluvial transportation from site to site.
3. In any case, tourism services in the study area are extremely limited accounting for 3,54% of the tourism nationwide (PNDTS 2011-2020). The San Juan River department is among the poorest in the country, and is therefore one of the regions of the country with least tourism services.
4. The city of San Carlos is the tourism distribution centre for the San Juan River (El Castillo, Sábalo, Solentiname Islands), but it does not offer visitors the necessary physical infrastructure to meet their needs. Visitation to this area does not reach beyond an estimated 10,000 visitors per year, a very small number to be able to consider developing a competitive and consolidated tourism.
5. Some of the lodgings that have appropriate facilities of a middle level, well integrated to the natural surroundings, are developing tourism products focused on international

visitors with an emphasis on eco-tourism: wildlife observation, tours within the reservations, specialized nature paths, fishing, etc. However, some of these have been unable to consolidate a visitation level that would allow them to reach their point of equilibrium, so that their services are seasonal and not year-round.

6. Tourism services concentrate mainly on nature observation, nature walks, boat tours and fishing. These activities concentrate in Sábalo, El Castillo and the Indio-Maíz Refuge and neighboring areas.
7. Even though sports fishing activities are widely provided in the region of San Carlos and neighboring areas such as El Castillo and Sábalo, no commercial or fishing activities were identified along the river for the study area. Fishing activities from Border Mark 2 to Delta Costa Rica is sporadic, subsistence fishing.
8. The tourism potential of the region is sufficient to justify attracting international visitors. However, infrastructural conditions, the state of access routes, the existing services and products offered, the quality of the existing offer, a weak image for the region, information and commercialization mechanisms of an incipient nature, are not sufficiently satisfactory to attract more visitors.
9. The previously mentioned factors, in addition to a climate of instability and insecurity in the region, generated by images of continuous border disputes between Costa Rica and Nicaragua, do not favor the kind of private investment that could strengthen tourism in the region.
10. All the same, Nicaragua (PNDTIS 2011-2020) points strongly to the San Juan River department as one of its priority destinations to strengthen and raise nature tourism in the country. To date, there are no significant changes in the flow of visitors. In some instances, the contrary is what is taking place, with important decreases in tourism visitation being reported, (see Chart 1).
11. The growth in visitation to San Carlos could increase further, though slightly, due to the new road that connects Managua with San Carlos, which has reduced travel to 4.5 hours. However, this new access seems to be attracting mainly local tourism and backpackers.
12. The use of fluvial transportation means that tourists travel mainly on public transportation services which have pre-established itineraries with very accessible costs (see Annex 1). On the other hand, private transportation services are costly and practically non-existent.
13. The profile of tourists who visit the region and specially those who visit across the San Juan River is mostly that of backpackers who are willing to pay minimally for very basic services.
14. To date, navigation on the river, requires extra investment due to the additional taxes that Costa Rican boats must pay when reporting to Nicaraguan authorities in San Carlos, in addition to the less than friendly requirements placed on tourists; conditions that add to the sense of insecurity and distrust in trying to conduct organized tourism.
15. The effect of the construction of Route 1856 has no direct impact on tourism in recent years.

4.2 On the route constructed

1. Landscape alterations resulting from the construction of Route 1856 create the possibility of natural or artificial regeneration of altered areas, natural or assisted regeneration, or the development of short and medium term reforestation projects with native species from the region.
2. The process of visual recovery of the landscape in the most affected area (between Tiricias and the mouth of the San Carlos River) has already been subjected to intervention with reforestation projects with the participation of local neighbors, offering an optimistic possibility of recuperation, or at least a first barrier or curtain of natural vegetation.
3. The flow of visitors or the potential tourism development that may lead to an increase in visitors through this means continues to be very modest; a condition that to some extent ensures that there will be no landscape alteration in the short and medium term.
4. In any case, as a result of the current reforestation processes a significant improvement could be expected in terms of the landscape that can be observed from the San Juan River.

5 RECOMMENDATIONS

1. It is of fundamental importance for the good image of the country, which represents a green country with a conservationist vocation, to implement the necessary initiatives to recover the plant cover of the affected zones, mainly exposed hillsides and slopes.
2. Efforts intent on the consolidation of plant cover should reinforce and recover some of the historical bad practices prior to the alterations produced by the Route, especially in all San Juan River margin areas, ensuring that the river margin is respected in the future.
3. Even though it is true that reforestation efforts being conducted by CODEFORSA make use of species from the region, it is recommended that fast growing species be used in order to lower the visual impacts in the short term. In the reforestation process it is also advisable to use species that can cover vertical spaces to serve as integral visual barriers starting at a height of 60 cm.
4. It is of basic importance that landscape recovery efforts be an integral process that includes the participation of local communities, for which purpose it is advisable to consider environmental education, community organization, entrepreneurship, local initiative and other. The purpose is not only reforestation but also that this region become an example of commitment and vision of a country that is seeking to be sustainable through integral, visionary work.
5. Given new access roads, distance and time improvements, access to energy resources and other services, this region has many possibilities of seeing new tourism initiatives in rural communities or in protected public and private areas in the midterm. This possibility could create development opportunities for local communities. It could eventually become a means to generate more tourism from Costa Rica to Nicaragua, as has been intended in the past.
6. According to the World Tourism Organization and related organizations, safety is the first condition required by tourists in order to visit an area. Therefore, as long as safety and security remain uncertain in the area of the Route, opportunities for visitation by international tourists who are not backpackers will remain limited.

6 BIBLIOGRAPHY

AECID, Araucaria XXI. 2006. Programa de la cooperación española para la sostenibilidad ambiental en América Latina. Managua, Nicaragua: AECID.

Arrieta, L. 2013. Informe sobre franja fronteriza. San José, Costa Rica: Cancillería de la República.

Boletín Estadístico de Turismo. 2012. Instituto de Turismo de Nicaragua. http://www.intur.gob.ni/index.php?option=com_content&view=article&id=27&Itemid=14

Cámara Nacional de Turismo de Nicaragua, sección Río San Juan. www.riosanjuancanatur.org

CODEFORSA. 2013. Consultoría para el Desarrollo e Implementación de un Plan de Gestión Ambiental en el Camino Fronterizo Juan Rafael Mora Porras. Informe de actividades para la Cancillería de la República de Costa Rica. San José, Costa Rica: SINAC.

Comisión Regional de la Iniciativa Mesoamericana de Turismo. (s.f.). Perfil de Proyecto. Ruta del Caribe Centroamericano.

Instituto de Turismo de Nicaragua. (s.f.). Plan Nacional de Desarrollo Turístico Sostenible de Nicaragua 2011-2020. Managua, Nicaragua: BID-INTUR-AECID.

Instituto de Turismo de Nicaragua. (s.f.). Plan de Desarrollo Turístico Sostenible de Nicaragua. Destino Río San Juan. Estrategia de desarrollo 2011-2020. Managua, Nicaragua: BID-INTUR-AECID.

Instituto de Turismo de Nicaragua. (s.f.). Plan Nacional de Desarrollo Turístico Sostenible de Nicaragua 2011-2020. Plan de Marketing. Managua, Nicaragua: BID-INTUR-AECID

Martínez-Sánchez, J.C. 2001. Biodiversidad zoológica en Nicaragua. Proyecto Estrategia Nacional de Biodiversidad y su Plan de Acción PNUD-NIC/99/G31-MARENA. Managua, Nicaragua: MARENA.

7 APPENDIX

7.1 Summary of companies and institutions consulted by phone call of personal communication.

COMPANY/INSTITUTION CONSULTED	LOCATION
COMPANIES	
Hotel Montecristo Lodge	Sábalo, Río San Juan, Nic.
Agua Trails	La Fortuna, Costa Rica
Aventuras Arenal	La Fortuna, Costa Rica
María José Paniagua	Consultora, Nicaragua
INSTITUTIONS	
Instituto Costarricense de Turismo	Costa Rica
Instituto Nicaragüense de Turismo	Nicaragua

7.2 Itineraries for public transportation services in the department of Rio San Juan

Nicaragua.

AIR TRANSPORTATION SERVICE
La Costeña aircrafts depart from Managua airport at 1:30 p.m., daily, arrive to San Carlos 2:15 pm, 45 min after takeoff. Aircrafts depart San Carlos 2:25pm., 15 min after disembarking passangers. Arrival to Managua 3:05 pm. Returning flight should be confirmed at the San Carlos terminal. Round trip ticket price is $116.00 La Costeña phone number in San Carlos is (505) 2583-0367 Address: ENACAL 60 varas al Norte, Sector 2. San Carlos

BY BOAT CROSSING THE GREAT LAKE OF NICARAGUA. (Lago Cocibolca)
The trip is 14 hours long and starst at the port city of Granada, from where ferry departs to Ometepe island, San Miguelito port and Morrito, arrives at San Juan river origination in San Carlos. Ferry departs twice a week from Granada, Monday and Thursday at 2:00 PM, crosses the lake of Nicaragua or Cocibolca. Stops at Altagracia in Ometepe island, Morrito and San Miguelito. Passes by Solentiname islands before arriving to San Carlos in the early morning, between 5 and 7am. Ticket Price is C$ 90.00 córdobas, economic class in load cabin, and C$ 180.00 Córdobas en upper part, which is refered to as “First Class”. AC, tables and TV are available here. They also offer a prívate cabin with two beds, fan, prívate bath, TV and DVD for C$1,000.00 one way. For more information call ENAP 2552-2966. The boat trip is uncomfortable, for which carrying a hammock to rest is recommended. It is chilly at night in the middle of the lake, and it might rain. A windbreaker and/or warm jacket is also recommended. Food and refreshments for sale aboard. Consuming alcoholic drinks or drugs is not allowed on board.

GROUND TRANSPORTATION
Buses depart from Mercado de Mayoreo in Managua 4 times a day, ticket price is C$160.00, the trip takes 9 hours to San Carlos.

FROM COSTA RICA.
From San José or La Fortuna to Los Chiles, in public buses departing from terminal, or prívate vehicles. From Los Chiles, Costa Rica to San Carlos, San Juan river in public boats departing twice a day at 1:00 y 3:00 PM, a 500 colones fee should be paid to Alcaldía and boat ticket price to San Carlos is $10.00. It is possible to rent a private boat to pick up passengers in Los Chiles at a negotiable time, 1 to 10 passengers is $320.00 the trip. San Carlos to Los Chiles, Monday through Saturday 10:30 pm, 1:30 pm and 4:00 pm C$200.00 or $9.50, Sunday 1:00 pm and 3:00 pm.

San Juan River – Boat Transportation

PUBLIC BOAT SCHEDULE

Departure Port	Time	Destination	Price
		Monday through Saturday	
San Carlos	8:00Am	Sábalos, MonteCristo, El Castillo	48.00 Cor
	12:00 Pm	Sábalos, MonteCristo, El Castillo	48.00 Cor
	1:00 Pm	Sábalos, MonteCristo, El Castillo	48.00 Cor
	2:00 Pm	Sábalos, MonteCristo, El Castillo	48.00 Cor
	3:00 Pm	Sábalos, MonteCristo, El Castillo	48.00 Cor
El Castillo	8:00Am	MonteCristo, Sábalos, San Carlos	48.00 Cor
	12:00 Pm	MonteCristo, Sábalos, San Carlos	48.00 Cor
	1:00 Pm	MonteCristo, Sábalos, San Carlos	48.00 Cor
	2:00 Pm	MonteCristo, Sábalos, San Carlos	48.00 Cor
	3:00 Pm	MonteCristo, Sábalos, San Carlos	48.00 Cor
		Sunday	
San Carlos	1:00Am	Sábalos, MonteCristo, El Castillo	48.00 Cor
El Castillo	5:00 Am	MonteCristo, Sábalos, El Castillo	48.00 Cor
	2:00 Am	MonteCristo, Sábalos, El Castillo	48.00 Cor
San Juan del Norte	5:00 Am	San Carlos	180.00 Cor
		Monday	
Papaturro	6:00 Am	San Carlos (4 hours)	45.00 Cor
		Tuesday	
San Carlos	6:00 Am	San Juan Del Norte (8 hours)	180.00 Cor
San Carlos	7:00 Am	Papaturro (4 hours)	45.00 Cor
		Thursday	
San Juan del Norte	5:00 Am	San Carlos (8 Hours)	180.00 Cor
Papaturro	6:00 Am	San Carlos (4 Hours)	45.00 Cor
		Friday	

San Carlos	6:00 Am	San Juan Del Norte (8 hours)	180.00 Cor
San Carlos	7:00 Am	Papaturro (4 Hours)	45.00 Cor

PRIVATE BOATS (EXPRESS TRIPS)

Prices per boat, max. 9 passengers per boat

San Carlos Monte Cristo	100.00 US. one way
	170.00 US round trip
San Carlos - El Castillo	140.00 US. one way
	170.00 US round trip
	25.00 US. waiting day
San Carlos - Solentiname	150.00 US. round trip to an island
	50.00 US. tour in the islands
	25.00 US. per waiting day
San Carlos - San Juan del Norte	950.00 US. round trip
	100.00 US. waiting day

9.3 Analysis of the structural connectivity in the landscape of Route 1856

Environmental Diagnostic Assessment
Ecological Component

Project Route 1856 "Juan Mora Porras"

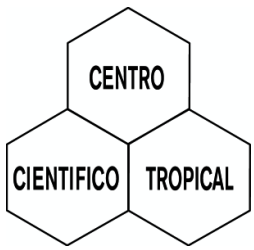
Analysis of the structural connectivity in the landscape of Route 1856

CENTRO CIENTIFICO TROPICAL

November, 2013.

Elaborated by:
Olivier Chassot Labastrou, PhD.

Analysis of the structural connectivity of Route 1856



Olivier Chassot L., PhD

Centro Científico Tropical
November, 2013

EXECUTIVE SUMMARY

The connectivity analysis of ecosystem fragments in the North Caribbean of Costa Rica indicates the existence of gaps in relation to the conservation goals. We analysed the degree of structural connectivity between 2454 nodes of natural ecosystem units with areas over 5 ha. The *integral index of connectivity* (IIC) of the landscape is 0.03, and the *probability of connectivity index* (PC) is 0.14 for a dispersal probability of 88% with a 500 m threshold. Both indices indicate a low percentage of connectivity in the landscape of the area of study. The most important nodes are located in the border area with Nicaragua and in the coastal area of the Caribbean. We highlight the fundamental importance of the Maquenque National Wildlife Refuge in relation to the other protected wildlife areas of the study area, as it provides essential connectivity nodes South as well as Northeast and East. We found that the establishment of Route 1856 in the area of study has a minimal effect on the connectivity of the landscape.

INTRODUCTION

The heterogeneous landscape of the North Caribbean of Costa Rica includes several fragmented ecosystems where conservation and sustainable development strategies have been implemented, along with significant financial investments by government institutions, national non-governmental organizations and international cooperation institutions. The humid tropical rainforest of the North Caribbean has undergone a strong fragmentation process, and the

ecological connectivity of the North Caribbean of Costa Rica has been significantly reduced (Chassot *et al*. 2002, Chassot *et al*. 2003, Sesnie *et al*. 2003, Ramos & Finegan 2007, Morse *et al*. 2009, Chassot 2010). With the establishment of Route 1856 in the border area of Costa Rica with Nicaragua, it is important to analyse the potential impact on the conservation of connectivity by identifying priority sites and critical connectivity linkages.

CONCEPTUAL FRAMEWORK

Connectivity

Connectivity is a vital element of landscape structure (Taylor *et al*. 1993). One of the strategies to mitigate the effects of fragmentation of ecosystems is maintaining or re-establishing landscape linkages (Noss 1991). Connectivity is described as "how the spatial arrangement and quality of elements in the landscape affect the movement of organisms among habitat patches" (Bennett 2004). Crome (1997) warns of the minimalist approach that consists of establishing that very small or relatively isolated fragments lack importance; he indicates that the baseline consists of understanding that the number of natural fragments in existence at a specific time is the minimum to be preserved. A large number of organisms have daily or temporary movement patterns that often take them from one fragment of an ecosystem to another. In terms of management, connectivity is manifested in biological corridors (Worboys 2010); however, corridors can represent both an opportunity for movement as well as a barrier for organisms, depending on the type of coverage of the corridor and of the specific organism (Hilty *et al*. 2006, Anderson & Jenkins 2006). Consequently, both the linkages of natural ecosystems and the surrounding matrix play an important role in the efficiency of ecological connectivity (Schelhas & Greenberg 1996, Crome 1997, Bierregaard & Stoufer 1997, Bennett *et al*. 2006). In the landscape, the value of connectivity will depend to a large extent on the behaviour of each organism in relation to the use of corridors (Soulé 1991, Bélisle 2005, Sanderson *et al*. 2006, Fagan & Calabrese 2006). Conservation strategies based on corridors consist of optimizing the width and variety of a natural habitat in landscape linkages so that the entire spectrum of native species has the opportunity to move among natural areas within the landscape (Noss 1991). Connectivity is also expressed in connectivity networks, which exist or are re-established among fragments of ecosystems that were separated by anthropogenic factors (Forman & Godron 1981, Bruinderink *et al*. 2003), allowing the free movement of organisms from one fragment to another (Dobson *et al*. 1999). The underlying idea of ecological networks is to identify the biological diversity and natural resources of the landscape, guided by conservation planning principles combined with information regarding the need to fill conservation gaps to preserve natural communities (Hoctor *et al*. 2000). Connectivity theory within landscape ecology and conservation biology indicates that it is probable that connectivity linkages have the capacity to mitigate, to a certain extent, the collateral effects of climate change on the need for movement of certain organisms, in response to the increase in annual temperatures (Noss 1991, Hay 1991, Dobson *et al*. 1999, Thomas *et al*. 2006). Connectivity provides two fundamental functions: Firstly, it allows the regular movement of organisms, ensuring that the various subdivisions of a population can maintain a genetic equilibrium (Soulé 1991, Britten & Baker 2002, Frankham 2006). Secondly, connectivity facilitates the dispersal between the home range of the species

and their migration areas (Harrison 1992, Dobson *et al*. 1999, Chassot *et al*. 2005). There are various scales of connectivity, namely: fragment, local, landscape and regional or continental (Taylor *et al*. 2006). The structural connectivity of the landscape is determined by the spatial distribution of the types of habitats, which depends on the continuity of habitats, the distance between the elements of the landscape and the size of the gaps between fragments (Theobald 2006). Behavioural connectivity is related to the behavioural response of the species to the structure of the landscape (Bennett 2004). The scale and design of the connectivity elements depends on the management goals and must be adapted to the focus species for which the corridor's maintenance or re-establishment is sought (Soulé 1991, De Campos & Finegan 2002, Bennett *et al*. 2006). Particularly, the definition of a dispersal threshold according to the needs of the organisms has significant implications, and it does not always correspond to other ecological thresholds (With 2002). These also depend on the potential ecological changes brought about by the uncertain impacts of climate change (Pearson 2006, Chester & Hilty 2010). There is a controversy that feeds the debate on the adequacy of corridors since the appearance of the concept, with the popularity of the theory of island biogeography (McArthur & Wilson 1967) and the hypothesis that corridors are a solution to increasing isolation in protected wildlife areas in the landscape matrix (Beier & Noss 1998). Some authors (Simberloff & Cox 1987, Simberloff *et al*. 1992, Hobbs 1992) warn of the cost of investment in corridors, and the potential danger of involuntary dissemination of certain organisms that lack natural connectivity, given that an artificial corridor can provide connectivity between fragments that were historically separated by other types of ecosystems, especially with regard to invasions of exotic species in natural ecosystems (Janzen 1986, Crooks & Suarez 2006) or diseases that can lead species to extinction (Hess 1994, McCallum & Dobson 2006). In some cases this attitude is due to the false premise that pre-agricultural landscapes were habitats comprised of homogeneous blocks (Dobson *et al*. 1999).

3

Fragmentation

The deforestation phenomenon causes a loss of nutrients in the ecosystem (Bormann *et al*. 1968) and it is accompanied by fragmentation processes, or reduction in size and increase in the isolation of forest fragments (Schelhas & Greenberg 1996, Sánchez *et al*. 2001), such as forest remnants, forests subjected to forestry management, natural forests, sacred forests and gallery forests or riparian forests. This phenomenon causes fragmentation processes, or reduction in the size and increase in the isolation of forest fragments (Lindenmayer & Fischer 2006), as well as an increase in the negative effect of natural or anthropogenic barriers (Clevenger & Wierzchowski 2006, Crooks & Sanjayan 2006). The fragmentation of ecosystems causes different impacts on the biota (Saunders *et al*. 1991, Laurance *et al*. 2002). The most drastic effect of forest fragmentation is the decrease in the population of wildlife organisms and the extinction of wildlife organisms in the fragment, local and landscape scales (Levin & Paine 1974, Jordan 1986, Franklin & Forman 1987, Collado & Dellafiore 2002, Kattan 2002, Gallego & Finegan 2004, Laurance *et al*. 2002, Laurance & Vasconcelos 2004, Santos & Telleria 2006, Haddad & Tewksbury 2006). Fragmented landscapes are subject to the constant actions of humans, which complicates the expansion of protected wildlife networks (Lindenmayer & Fischer 2006). These fragments can contain a number of organisms absent from the protected wildlife areas (Schelhas & Greenberg 1996). Even a matrix composed of different types of

dynamic agro-landscapes maintains important ecological functions (Gascon *et al*. 2004, Bennett *et al*. 2006). It is important to consider the landscape as a whole instead of as a collection of separate biotic entities (Saunders *et al*. 1991).

In the tropical regions where forest cover loss processes have been severe, fragments may play an important role as seed banks, sources of seed dispersal (Guariguata *et al*. 2000), buffering zones for intact forest patches, providing resources for a large number of organisms that use biological corridors and acting as a refuge for local or long-distance migrating organisms (Greenberg 1996, Bennett 2004).

Fragmentation forces several organisms that were previously present in continuous connected habitats to act as metapopulations or remnants of natural ecosystems (Lefkovitch & Fahrig 1985, Opdam *et al*. 1985, Gilpin & Hanski 1991, McCullough 1996, Moilanen & Hanski 2006) and to move between fragments of natural ecosystems (Dale *et al*. 1994). On the other hand, fragmentation exposes forest organisms to the edge effect (Lovejoy *et al*. 1986), causing increases in the level of sunlight, invasion of organisms from open areas, (Laurance *et al*. 1985), drying processes due to the penetrating effect of wind (Laurance 1997) and changes in the characteristics of the vegetation structure (Lovejoy *et al*. 1997, Lezcano *et al*. 2002, Lindenmayer & Fischer 2006). However, an investigation of the area of the study shows that the edges of the remnants of humid tropical rainforest have recovered after two decades of being exposed to the surrounding matrix (Forero & Finegan 2002, Schedlbauer *et al*. 2007, Finegan & Bouroncle). A fragment can be too small to provide sufficient food sources to organisms with broad home ranges, or it can only support small populations which are subject to high risks of extinction due to various factors, including stochastic variations in population size (Andersen *et al*. 1997). The organisms' response to fragmentation processes depends on the degree of ecological specialization, body size and movement patterns (Kellman *et al*. 1996, Guindon 1996, Tewksbury *et al*. 2006). A large number of the ecological processes whereby organisms are affected by the edge effect, whether natural or provoked, have not been understood yet (Harris 1988); however, some studies point to a decline in richness and abundance of fauna (Willis 1974, Ernst *et al*. 2006, Lees & Peres 2006) and long-term effects on the pollination processes of vegetation species that lack the capacity to move among isolated fragments (Murcia 1996, Manning *et al*. 2006, Hanson *et al*. 2007, Hanson *et al*. 2008), especially in places with high biodiversity indexes and where plants and trees are subject to a greater occurrence of decline or extinction due to a lack of specialized pollinators (Vamosi *et al*. 2006). Cramer *et al*. (2007) have demonstrated how tree species whose seeds are dispersed by medium and large animals have a greater difficulty of dispersal of their genes in fragmented landscapes. Fragmentation processes and their ecological implications are extremely complex (Crome 1997) and require greater applied research efforts (Bierregaard *et al*. 1997).

METHODOLOGICAL FRAMEWORK

Methodology

The general methodology follows Chassot (2010) and encompasses the following steps:

1. Define the study area
2. Compile the information available
3. Incorporate the information compiled in the Geographic Information System
4. Classify the vegetation and land use cover, with input from the Landsat (2005) satellite images
5. Analysis of structural connectivity

Connectivity indices

We calculated the *integral index of connectivity* (IIC) and the *probability of connectivity index* (PC) using the program Conefor Sensinode 2.2 (Saura & Pascual 2007b). This program allows quantifying the importance of habitat fragments to maintain landscape connectivity by means of graph structures and habitat availability indices. The program's inputs and outputs are expressed by means of ASCII files, which can be manipulated in ArcView (ESRI 2004, ESRI s.f.). The *IIC* is descriptive; it represents the degree of connectivity of the landscape. On the other hand, the *PC* is based on the concept of habitat availability and probability of generic dispersal between fragments. The *PC* expresses an estimate of the strength, frequency and feasibility of dispersal between two or more fragments, and it indicates the probability that two organisms located in any habitat fragment in the landscape can disperse. These indices also allow identifying the fragments or nodes that are of greater structural importance for connectivity and that react to changes in the landscape structure, which is a useful tool in terms of habitat conservation planning (Opdam 2002, Pascual & Saura 2006, Saura & Pascual 2007a). We calculated the euclidean distance (Urban & Keitt 2001) between the edges of all fragments equal to or greater than 5 hectares (N=2454), applying an arbitrary dispersal threshold of 500 metres (Villard *et al*. 1999).

5

Structural connectivity network

Habitat networks offer a solution for fragmentation (Opdam 2002). First, we identified the nodes or linkages of greater structural importance within the area of study according to the results of the *IIC* and *PC* indices (with the program Conefor Sensinode 2.2), which correspond to basic landscape measurements such as fragment size, distance to closest fragment (Kramer 1997, Corra do Carmo *et al*. 2001). The nodes were classified on a priority scale of very high, high, medium, low or very low. We adapted the methodology of Hoctor *et al*. (2000), applied in the different structural connectivity analyses of the biological corridors in Costa Rica (Ramos 2004, Murrieta *et al*. 2007, Ramos & Finegan 2007, Baltodano & Zamora 2009). The planning units of the analysis are the ecosystem units, including natural forest cover, secondary forest

and bodies of water. On the other hand, we establish the connectivity routes through an analysis of the connection with the least cost path, where cost is a function of the friction determined through the *Cost Distance* and *Cost Path* functions on a *raster* in the extension *Spatial Analyst* of ArcGIS 9.x (Walker & Craighead 1997, Hoctor *et al*. 2000, Rouget *et al*. 2004, Kautz *et al*. 2006). The least cost path is calculated based on a friction map, which indicates which elements of the landscape represent greater resistance to the movement of organisms (grade of friction: forest = 1, secondary forest = 2, body of water = 3, agricultural = 4, uncovered soil = 5, banana = 6, pineapple = 7). We took the five connectivity nodes of greatest structural importance on the east, west, north and south sides of the landscape to generate the different connectivity routes, select the main routes and identify priority areas of connectivity.

RESULTS

Connectivity indices

We integrated 2454 nodes of natural ecosystem units with a size equal to or greater than 5 hectares based on the classification of Landsat TM 2005 satellite images (source: University of Alberta, Canada) performed by Chassot (2010). These nodes generated 3827 connections. The *integral index of connectivity* (IIC) of the landscape is 0.03, and the *probability of connectivity index* (PC) is 0.14 for a dispersal probability of 88% with a 500 m threshold. Both indices indicate a low percentage of connectivity in the landscape of the area of study (Moilanen & Hanski 2001). In our case, the *PC* indicates that there is a 14% probability that two animals located in any fragment of the habitat within the landscape, with the capacity of moving over distances equal to or less than 500 meters, can meet. On the other hand, the calculation of the *Delta value* (dI) of each fragment – derived from the connectivity analysis – allows prioritizing the most important fragments in terms of global connectivity (Rae *et al*. 2007). These are the most relevant elements of the landscape to maintain connectivity, meaning the elements whose absence has an impact on the connectivity between large fragments of natural cover and on the global quality of the group of habitat fragments; therefore, they offer a spatial representation for the prioritization of management actions geared toward improving the quality of the habitat in the landscape (Figure 1).

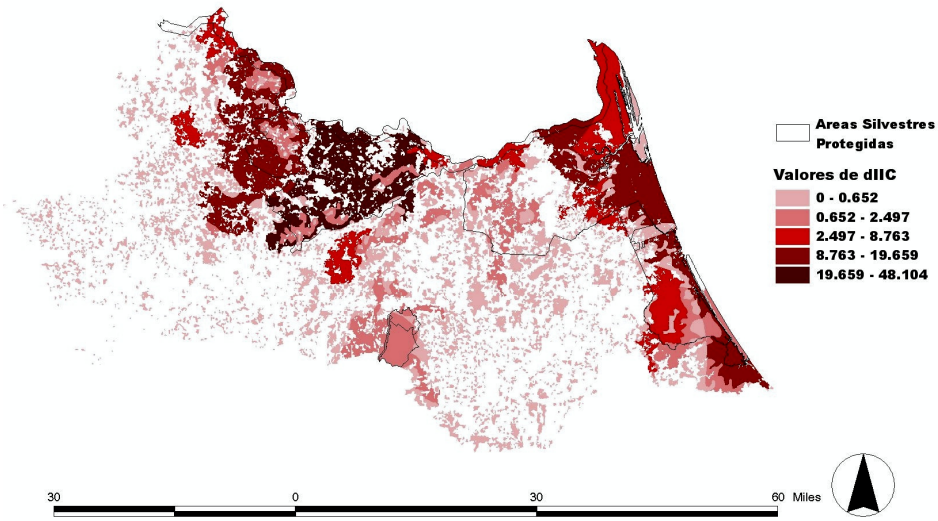


Figure 1: Prioritization of the nodes to maintain structural connectivity of the landscape (*dIIC* – higher values indicate higher priority), (Chassot 2010)

The importance of a specific node reflects, in general, the intrinsic characteristics of the habitat (in our case, the area) and the topological position within the landscape network (for example, a node fulfilling a linkage function). The notes with the highest *Delta values* (dIIC) are those of greater importance for the connectivity between fragments and within fragments (Pascual & Saura 2006). In addition, the largest nodes could maintain the internal sources of recolonization (Fahrig & Merriam 1994) and sustain large populations (Pickett & Thompson 1978).

7

The most important connectivity nodes of the landscape correspond to areas of greater forest cover, located on the eastern portion of RNVS Maquenque, as well as the western portion of said refuge and the coastal area of PN Tortuguero and RNVS Barra del Colorado. In general, the connectivity nodes of greater importance (medium, high and very high) are adequately represented in the protected areas system (50.2%), except for certain sectors on the northwest of RNVS Maquenque in the area Tiricias-Crucitas (Pocosol and Infiernito districts), to the southwest of RNVS Maquenque in the area of San Marcos-Almendros-Castelmare (Cutris district), to the south of RNVS Maquenque between the communities of Sahino and Quebrada Grande (Tres Amigos district), another sector further south of RNVS Maquenque, along the south bank of Río Toro, in a sector between the communities Pangola and Sardinal (Río Cuarto district), and south of PN Tortuguero. The RNVS Border Corridor, on which Route 1856 is located, plays a major role in maintaining structural connectivity. We observe that the most important nodes are located on the border area with Nicaragua, and in the entire Caribbean coastal area. Due to their latitudinal orientation, these offer the capacity of intercepting the north-south fauna immigration corridors and maintaining the recolonization processes of the fragments of natural ecosystems (Gutzwiller & Anderson 1992, Freemark *et al*. 2002). We note the lower relative importance of ZP La Selva and PN Braulio Carillo (due to their peripheral location in the area of study at higher levels), and of the western sector of RNVS Barra del

Colorado in maintaining the structural connectivity of the ecosystem units of the plains of the North Caribbean. Finally, we highlight the fundamental importance of RNVS Maquenque in relation to the other protected wildlife areas, as it provides essential connectivity nodes to the south as well as to the northeast and east.

Structural connectivity network

Our analysis of the different connectivity routes originating from the geographic points of the five priority nodes to maintain the structural connectivity of the landscape indicates that the majority of the connectivity proposals are located on the protected wildlife areas adjacent to San Juan River and on the Caribbean coast (Figure 2, Chassot 2010).

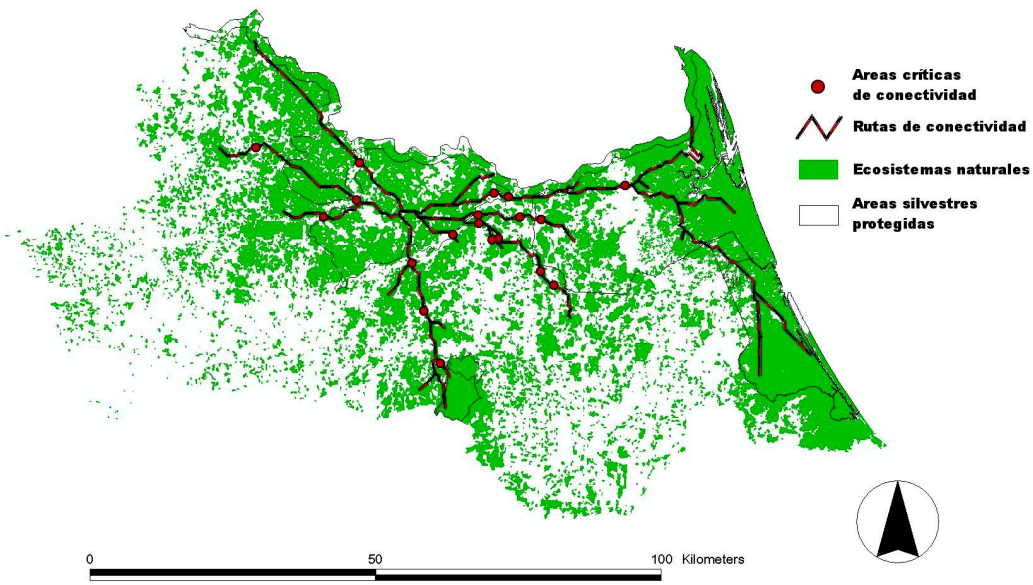


Figure 2: Priority routes of landscape connectivity (Chassot 2010)

RNVSM Maquenque provides connectivity routes to the northwest, to the east and to the south. In this regard, Maquenque's location is strategic in the context of the landscape. We identified 18 priority areas for structural connectivity based on the nodes or connections of greater structural importance within the area of study, none of which are related to the layout of Route 1856.

Table 1: Characterization of the priority areas of connectivity

No	Name	Canton	Coordinates Lambert North	Connectivity node
1	Río Tico-Moravia	San Carlos	497500/305500	Jardín - Coopevega
2	Recreo-San Carlos	San Carlos	515800/302800	Maquenque – Río San Carlos
3	Santa Rita	San Carlos	515100/296 300	Maquenque – Río San Carlos
4	Boca Tapada	San Carlos	509300/293200	Maquenque – Río San Carlos

5	Mollejón	Sarapiquí	524800/285300	Maquenque – Braulio Carrillo
6	Sardinal	Sarapiquí	527000/276900	Maquenque – Braulio Carrillo
7	Chilamate	Sarapiquí	529800/267600	Maquenque – Braulio Carrillo
8	Golfito	Sarapiquí	531900/290300	Maquenque – Braulio Carrillo
9	Arbolitos	Sarapiquí	535500/292200	Maquenque – Barra Colorado
10	Unión del Toro	Sarapiquí	536400/293700	Maquenque – Barra Colorado
11	Trinidad 1	Sarapiquí	539100/297600	Maquenque – Barra Colorado
12	Trinidad 2	Sarapiquí	541900/296800	Maquenque – Barra Colorado
13	Ruta Este Superior	Sarapiquí	562200/298800	Maquenque – Barra Colorado
14	Ruta Este Mediana 1	Sarapiquí	543600/293400	Maquenque – Barra Colorado
15	Ruta Este Mediana 2	Sarapiquí	547400/293000	Maquenque – Barra Colorado
16	Ruta Este Inferior 1	Sarapiquí	539400/289500	Maquenque – Barra Colorado
17	Ruta Este Inferior 2	Sarapiquí	547400/283900	Maquenque – Barra Colorado
18	Ruta Este Inferior 3	Sarapiquí	549700/281500	Maquenque – Barra Colorado

Of the 18 priority connectivity areas, 10 have the potential of maintaining and strengthening the connectivity routes between RNVSM Maquenque and RNVS Barra del Colorado in areas of agricultural use with low demographic density and marshlands that are not suitable for production activities. Between RNVSM Maquenque and Parque Nacional Braulio Carrillo there are 4 critical areas located on the north-south axis, in areas of agricultural use and subject to the progress of intensive single crops (mainly pineapple) on the banks of the rivers Toro, Sardinal and Sarapiquí which cross the axis toward the northeast. There are 3 priority areas located on the course of San Carlos River, between the two conservation blocks of RNVSM Maquenque. Finally, there is a priority area that allows extending connectivity between the western block of Maquenque and Coopevega area to the west.

The identification of the connectivity routes and the priority areas of connectivity in the landscape of the area of study agrees with 6 of the 7 critical areas identified by Ramos (2004) in the territory of the Biological Corridor of San Juan-La Selva. Of the 18 priority areas of connectivity, 13 are located along the course of important bodies of water such as the rivers San Carlos, Toro Amarillo, Sarapiquí and Sardinal, which indicates a high potential to implement projects for ecological restoration and protection of riverside vegetation. The area between national wildlife refuge Maquenque and Barra del Colorado is a place of strategic importance to maintain and re-establish the structural connectivity of the landscape.

CONCLUSION

In the North Caribbean of Costa Rica the increase in fragmentation (Chassot 2010) is consistent with the study by Schelhas and Sánchez (2006) in the vicinity of the intermediate lower watershed of Sarapiquí River, including part of Braulio Carrillo National Park and La Selva Biological Reserve. Similar to Morse *et al*. (2009), we attributed the decrease in the

reforestation rate from 1998 to 2005 in comparison to the previous period (1987-1998) to the enactment of Forestry Law 7575 (Chassot 2010), which explicitly prohibits land use change.

The identification of the connectivity routes and priority areas of connectivity in the landscape of the area of study demonstrate that they are not related to the layout of Route 1856, even though this border road is located in the area of greatest forest cover of the area of study. Similarly, it can be stated that Route 1856, due to the reduced extension of the affected natural ecosystem (83 ha), has not generated a significant impact on the structural connectivity of the landscape subject to this study.

The analysis of the landscape structure in the North Caribbean of Costa Rica indicates the existence of gaps in the biodiversity conservation goals and their ecosystems in the Atlantic watershed of the country. On the other hand, it evokes a dynamic and heterogeneous landscape that can have an impact on processes of ecological succession, adaptation, maintenance of diversity of species, stability of communities, competition, interaction between predators and prey, parasitism, epidemics and other stochastic events (Legendre & Fortín 1989). Conversely, the increase in heterogeneity detected in the landscape over time (Chassot 2010) allows suggesting that some species could benefit from this (Dauber *et al*. 2003). Therefore, we recommend integrating ecological, social and economic variables in a connectivity analysis to establish a functional conservation landscape that is feasible from a biocentric and anthropocentric perspective. This landscape will seek to prevent local extinction of the organisms that live the evergreen tropical broadleaf rainforest of the Costa Rican Atlantic, considering that these plain topographic areas could be subject to greater changes in use than slope areas (Kemper *et al*. 2000).

Thanks to the focus on landscape ecology, the design of a functional conservation landscape for protected wildlife areas and their buffering zones will allow identifying priority areas of natural habitats and promote ecological connectivity, taking into account the continuity of the ecosystems characteristic of the North Caribbean of Costa Rica and the socio-economic factors that affect the land use decision by the local communities, reflected in the structural definition of a zoning proposal based on priority linkages.

BIBLIOGRAPHY

Andersen M, Thornhill A, Koopowitz H. 1997. Tropical forest disruption and stochastic biodiversity losses. In Laurance WF, Bierregaard RO. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Chicago: The University of Chicago Press, 281-291.

Anderson A., Jenkins C.N. 2006. Applying nature's design. Corridors as a strategy for biodiversity conservation. New York, University of Columbia Press, X + 231 p.

Baltodano A, Zamora JC. 2009. Estrategia para la consolidación de la conectividad en un sector del Corredor Biológico San Juan-La Selva: un esfuerzo para la preservación de las rutas de migración en los ecosistemas mesoamericanos. San José, Costa Rica, Escuela de Geografía, Universidad de Costa Rica (tesis de licenciatura), 118 p.

Beier P, Noss RF. 1998. Do habitat corridors provide connectivity? Conservation Biology 12: 1241-1252.

Bélisle M. 2005. Measuring landscape connectivity: the challenge of behavioral landscape ecology. Ecology 86(8): 1988-1995.

Bennett AF, Radford JQ, Haslem A. 2006. Properties of land mosaics: implications for nature conservation in agricultural environments. Biological Conservation 133: 250-264.

Bennett AF. 2004. Enlazando el paisaje: el papel de los corredores y la conectividad en la conservación de la vida silvestre. San José, Costa Rica, Unión Mundial para la Conservación de la Naturaleza (UICN), XIV, 276 p.

Bierregaard RO, Laurance WF, Sites JW, Lynam AJ, Didham RK, Andersen M, Gascon C, Tocher MD, Smith AP, Viana VM, Lovejoy TE, Sieving KE, Kramer EA, Restrepo C, Moritz C. 1997. Key priorities for the study of fragmented tropical ecosystems. In Laurance WF, Bierregaard RO. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Chicago, The University of Chicago Press, 515-525.

Bierregaard RO, Stouffer PC. 1997. Understory birds and dynamic habitat mosaics in amazonian rainforests. In Laurance WF, Bierregaard RO. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Chicago, IL, University of Chicago Press, 138-155.

Bormann FH, Likens GE, Fisher DW, Pierce RS. 1968. Nutrient loss accelerated by clear-cutting of a forest ecosystem. Science 159: 882-884.

Britten HB, Baker RJ. 2002. Landscape connections and genetic diversity. In Gutzwiller KG. (ed.). Applying landscape ecology in biological conservation. New York, Springer, 131-149.

Bruinderink GG, van der Sluis T, Lammertsma D, Opdam P, Pouwels R. 2003. Designing a coherent ecological network for large mammals in northwestern Europe. Conservation Biology 17(2): 549-558.

Chassot O. 2010. Diseño de un paisaje funcional de conservación para el Caribe Norte de Costa Rica. Cartago, Costa Rica: Instituto Tecnológico de Costa Rica, Tesis de Doctorado em Ciencias Naturales para el Desarrollo.

Chassot O, Monge G, Powell GVN, Wright P, Palminteri S. 2005. El Corredor Biológico San Juan-La Selva: un proyecto del Corredor Biológico Mesoamericano para la conservación de la lapa verde y su hábitat. San José, Costa Rica, Centro Científico Tropical, 98 p.

Chassot O, Monge G, Ruiz A, Mariscal T. 2002. Acciones tico-nicas por la lapa verde en la cuenca del San Juan. Ambientico 105: 20-21.

Chassot O, Monge G, Ruiz A, Mariscal T. 2003. Corredor biológico Costa Rica-Nicaragua pro lapa verde. Ambientico 114: 21-23.

Chester CC, Hilty JA. 2010. Connectivity science. In Worboys GL, Francis WL, Lockwood M. (eds.). Connectivity conservation management. London, Earthscan, 22-33.

Clevenger AP, Wierzchowski J. 2006. Maintaining and restoring connectivity landscapes fragmented by roads. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 502-535.

Collado AD, Dellafiore CM. 2002. Influencia de la fragmentación del paisaje sobre la población del venado de las pampas en el sur de la provincia de San Luis. Revista de Investigaciones Agropecuarias 31(2): 39-56.

Cramer JM, Mesquita RCG, Williamson GB. 2007. Forest fragmentation differentially affects seed dispersal of large and small-seeded tropical trees. Biological Conservation 137: 415-423.

Crome FHJ. 1997. Researching tropical forest fragmentation: shall we keep on doing what we're doing? In Laurance WF, Bierregaard RO. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Chicago, IL, University of Chicago Press, 485-501.

Crooks KR, Sanjayan M. 2006. Connectivity conservation: maintaining connections for nature. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 1-19.

Crooks KR, Suarez AV. 2006. Hyperconnectivity, invasive species, and the breakdown of barriers dispersal. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 451-478.

Dale VH, Pearson SM, Offerman HL, O'Neill RV. 1994. Relating patterns of land-use change to faunal biodiversity in the central Amazon. Conservation Biology 8: 1027-1036.

Dauber J, Hirsch M, Simmering D, Waldhardt R, Otte A, Wolters, V. 2003. Landscape structure as an indicator of biodiversity: matrix effects on species richness. Agriculture, Ecosystems & Environment 98(1-3): 321-330.

De Campos DP, Finegan B, 2003. Principios, criterios e indicadores para la evaluación de corredores biológicos y su aplicación: caso Costa Rica. Revista Forestal Centroamericana 38: 9-13.

Dobson A, Ralls K, Foster M, Soulé ME, Simberloff D, Doak D, Estes JA, Mills LS, Mattson D, Dirzo R, Arita H, Ryan S, Norse EA, Noss RF, Johns D. 1999. Corridors: reconnecting fragmented landscapes. In Soulé ME, Terborgh J. (eds.). Continental conservation: scientific foundations of regional reserve networks. Washington, DC, Island Press, 129-170.

Environmental Systems Research Institute (ESRI). 2004. What Is ArcGIS? Redlands, CA, ESRI, 119 p.

Environmental Systems Research Institute (ESRI). S.f. ArcView 3.x. (computer software). Redlands, CA, ESRI.

Ernst R, Linsenmair KE, Rödel MO. 2006. Diversity erosion beyond the species level: dramatic loss of functional diversity after selective logging in two tropical amphibian communities. Biological Conservation 133: 143-155.

Fagan WF, Calabrese JM. 2006. Quantifying connectivity: balancing metric performance with data requirements. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 297-317.

Fahrig L, Merriam G. 1994. Conservation of fragmented populations. Conservation Biology 8(1): 50-59.

Finegan B, Bouroncle C. 2008. Patrones de fragmentación de los bosques de tierras bajas, su impacto en las comunidades y especies vegetales y propuestas para su mitigación. In Harvey CA, Sáenz JC. (eds.). Evaluación y conservación de biodiversidad en paisajes fragmentados de Mesoamérica. Santo Domingo, Heredia, Costa Rica, Instituto Nacional de Biodiversidad (INBio), 139-178.

Forero A, Finegan B. 2002. Efectos de borde en la vegetación de remanentes de bosque muy húmedo tropical en el norte de Costa Rica, y sus implicaciones para el manejo y la conservación. Revista Forestal Centroamericana 38: 39-43.

Forman RT, Godron M. 1981. Patches and structural components for a landscape ecology. BioScience 31(10): 733.740.

Frankham R. 2006. Genetics and landscape connectivity. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 72-96.

Franklin JF, Forman RTT. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecology 1: 5-18.

Freemark K, Bert D, Villard MA. 2002. Patch, landscape, and regional-scale effects on biota. In Gutzwiller KG. (ed.). Applying landscape ecology in biological conservation. New York, Springer, 58-83.

Gallego B, Finegan B. 2004. Evaluación de enfoques para la definición de especies arbóreas indicadoras para el monitoreo de la biodiversidad en un paisaje fragmentado del Corredor Biológico Mesoamericano. Recursos Naturales y Ambiente 2004: 49-61.

Gascon C, da Fonseca GAB, Sechrest W, Billmark KA, Sanderson J. 2004. Biodiversity conservation in deforested and fragmented tropical landscapes: an overview. In Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL, Izac AMN. (eds.). Agroforestry and biodiversity conservation in tropical landscapes. Washington, DC, Island Press, 15-32.

Gilpin ME, Hanski I. (eds.). 1991. Metapopulation dynamics: empirical and theoretical investigations. San Diego, CA, Academic Press, 336 p.

Greenberg R. 1996. Managed forest patches and the diversity of birds in southern Mexico. In Schelhas J, Greenberg R. (eds.). Forest patches in tropical landscapes. Washington, DC, Island Press, 59-90.

Guariguata M, Rosales J, Finegan B. 2000. Seed removal and fate in two selectively logged lowland forests with constrasting protection levels. Conservation Biology 14(4): 1046-1054.

Guindon C. 1996. The importance of forest fragments to the maintenance of regional biodiversity in Costa Rica. In Schelhas J, Greenberg R. (eds.). Forest patches in tropical landscapes. Washington, DC, Island Press, 168-186.

Gutzwiller KJ, Anderson SH. 1992. Interception of moving organisms: influences of patch shape, size, and orientation on community structure. Landscape Ecology 6: 293-303.

Haddad NM, Tewksbury JJ. 2006. Impacts of corridors on populations and communities. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 390-415.

Hanson TR, Brunsfeld SJ, Finegan B, Waits LP. 2007. Conventional and genetic measures of seed dispersal for Dipteryx panamensis (Fabaceae) in continuous and fragmented Costa Rican rain forest. Journal of Tropical Ecology 23: 1-8.

Hanson TR, Brunsfeld SJ, Finegan B, Waits LP. 2008. Pollen dispersal and genetic structure of the tropical tree Dipteryx panamensis in a fragmented Costa Rican landscape. Molecular Ecology 17: 2060-2073.

Harris LD. 1988. Edge effects and the conservation of biotic diversity. Conservation Biology 2: 330-332.

Harrison RL. 1992. Towards a theory of inter-refuge corridor design. Conservation Biology 6: 293-295.

Hay KG. 1991. Greenways and biodiversity. In Hudson E. (ed.). Landscape linkages and biodiversity. Washington, DC, Island Press, 162-175.

Hess GR. 1994. Conservation corridors and contagious diseases: a cautionary note. Conservation Biology 8: 256-262.

Hilty JA, Lidicker WZ, Merenlender AM. 2006. Corridor ecology: the science and practice of linking landscapes for biodiversity conservation. Washington, DC, Island Press, XIX, 323 p.

Hoctor TS, Carr MH, Zwick PD. 2000. Identifying a linked reserve system using a regional landscape approach: the Florida ecological network. Conservation Biology 14(4): 984-1000.

Janzen DH. 1986. The eternal external threat. In Soulé M. (ed.). Conservation biology: the science of scarcity and diversity. Sunderland, MS, Sinauer Associates, 286-303.

Jordan CF. 1986. Local effects of tropical deforestation. In Soulé M. (ed.). Conservation biology: the science of scarcity and diversity. Sunderland, MS, Sinauer Associates, 410-426.

Kattan G. 2002. Fragmentación: patrones y mecanismos de extinción de especies. In Guariguata M, Kattan G. (comp.). Ecología y conservación de bosques neotropicales. Cartago, Costa Rica: Libro Universitario Regional, 561-590.

Kautz R, Kawula R, Hoctor T, Comiskey J, Jansen D, Dawn J, Kasbohm J, Mazzotti F, Mcbride R, Richardson L, Root K. 2006. How much is enough? Landscape-scale conservation for the Florida panther. Biological Conservation 130(1): 118-133.

Kellman M, Tackaberry R, Meave J. 1996. The consequences of prolonged fragmentation: lessons from tropical gallery forests. In Schelhas J, Greenberg R. (eds.). Forest patches in tropical landscapes. Washington, DC, Island Press, 37-58.

Kemper J, Cowling RM, Richardson DM, Forsyth GG, McKelly DH. 2000. Landscape fragmentation in South Coast Renosterveld, South Africa, in relation to rainfall and topography. Austral Ecology 25(2): 179-186.

Kramer EA. 1997. Measuring landscape changes in remnant tropical dry forests. In Laurance WF, Bierregaard RO. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Chicago, University of Chicago Press, 386-399.

Laurance WF, Bierregaard RO, Gascon C, Didham RK, Smith AP, Lynam AJ, Viana VM, Logan W, Brown ER, Longrie D, Herb G. 1985. Edges. In Brown ER. (ed.). Management of wildlife and fish

habitats in forests of Western Oregon and Washington. Portland, OR, Department of Agriculture, Forest Service, 115-127.

Laurance WF, Lovejoy TE, Vasconcelos HL, Bruna EM, Didham RK, Stouffer PC, Gascon C, Bierregaard RO, Laurance SG, Sampaio E. 2002. Ecosystem decay of Amazonian forest fragments: a 22-year investigation. Conservation Biology 16(3): 605-618.

Laurance WF, Vasconcelos HL. 2004. Ecological effects of habitat fragmentation in the tropics. In Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL, Izac AMN. (eds.). Agroforestry and biodiversity conservation in tropical landscapes. Washington, DC, Island Press, 487-501.

Laurance WF. 1997. Hyper-disturbed parks: edge effects and the ecology of isolated rainforest reserves in tropical Australia. In Laurance WF, Bierregaard RO. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Chicago: The University of Chicago Press, 71-83.

Lees AC, Peres CA. 2006. Rapid avifaunal collapse along the Amazonian deforestation frontier. Biological Conservation 133: 198-211.

Lefkovitch LP, Fahrig L. 1985. Spatial characteristics of habitat patches and population survival. Ecological Modeling 30: 297-308.

Legendre P, Fortin MJ. 1989. Spatial pattern and ecological analysis. Vegetatio 80: 107-138.

Levin SA, Paine RT. 1974. Disturbance, patch formation and community structure. Proceedings of the National Academy of Sciences 71(7): 2744-2747.

Lezcano H, Finegan B, Condit R, Delgado D. 2002. Variación de las características de la comunidad vegetal en relación al efecto de borde en fragmentos de bosque, Las Pavas, Cuenca del Canal de Panamá. Revista Forestal Centroamericana 38: 33-38.

Lindenmayer DB, Fischer J. 2006. Habitat fragmentation and landscape change: an ecological and conservation synthesis. Washington, DC, Island Press, XVIII, 329 p.

Lovejoy TE, Bierregaard RO, Rylands AB, Malcolm JR, Quintela CE, Harper LH, Brown KS, Powell AH, Powell GVN, Schubart HOR, Hays MB. 1986. Edge and other effects of isolation on Amazon forest fragments. In Soulé M. (ed.). Conservation biology: the science of scarcity and diversity. Sunderland, MS, Sinauer Associates, 257-285.

Lovejoy TE, Sieving KE, Sites JW, Andersen M, Tocher MD, Kramer EA, Restrepo C, Moritz C. 1997. Tropical forest fragmentation: synthesis of a diverse and dynamic discipline. In Laurance WF, Bierregaard RO. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Chicago: The University of Chicago Press, 502-514.

MacArthur R, Wilson E. 1967. The theory of island biogeography. Princeton, Princeton University Press, 224 p.

Manning AD, Fischer J, Lindenmayer DB. 2006. Scattered trees are keystone structures: implications for conservation. Biological Conservation 132: 311-321.

McCullough DR. (ed.). 1996. Metapopulations and wildlife conservation. Washington, DC, Island Press, X, 429 p.

McCallum H, Dobson A. 2006. Disease and connectivity. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 479-501.

Moilanen A, Hanski I. 2006. Connectivity and metapopulation dynamics in highly fragmented landscapes. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 44-71.

Morse WC, Schedlbauer JL, Sesnie SE, Finegan B, Harvey CA, Hollenhorst SJ, Kavanagh KL, Stoian D, Wulfhorst JD. 2009. Consequences of environmental service payments for forest retention and recruitment in a Costa Rican biological corridor. Ecology and Society 14(1): 23.

Murcia C. 1996. Forest fragmentation and the pollination of neotropical plants. In Schelhas J, Greenberg R. (eds.). Forest patches in tropical landscapes. Washington, DC, Island Press, 19-36.

Murrieta E, Finegan B, Delgado D, Villalobos R, Campos JJ. 2007. Propuesta para una red de conectividad ecológica en el Corredor Biológico Volcánica Central Talamanca, Costa Rica. Recursos Naturales y Ambiente 51-52: 69-76.

Noss RF. 1991. Landscape connectivity: different functions at different scales. In Hudson E. (ed.). Landscape linkages and biodiversity. Washington, DC, Island Press, 27-39.

Opdam P, Rijsdijk G, Hustings F. 1985. Bird communities in small woods in an agricultural landscape: effects of area and isolation. Biological Conservation 34: 333-352.

Opdam P. 2002. Assessing the conservation potential of habitat networks. In Gutzwiller KG. (ed.). Applying landscape ecology in biological conservation. New York, Springer, 381-404.

Pascual Hortal L, Saura S. 2006. Comparison and development of new graph-based landscape connectivity indices: towards the priorization of habitat patches and corridors for conservation. Landscape Ecology 21(7): 959-967.

Pearson RG. 2006. Climate change and the migration capacity of species. Trends in Ecology and Evolution 21(3): 111-113.

Pickett STA, Thompson JN. 1978. Patch dynamics and the design of nature reserves. Biological Conservation 13: 27-37.

Rae C, Rothley K, Dragicevic S. 2007. Implications of error and uncertainty for an environmental planning scenario: a sensitivity analysis of GIS-based variables in a reserve design exercise. Landscape Urban Planning 79(3-4) 210-217.

Ramos ZS, Finegan B. 2007. Red ecológica de conectividad potencial: estrategia para el manejo del paisaje en el Corredor Biológico San Juan-La Selva. Recursos Naturales y Ambiente 49: 112-123.

Ramos ZS. 2004. Estructura y composición de un paisaje boscoso fragmentado: herramienta para el diseño de estrategias de conservación de la biodiversidad. Turrialba, Costa Rica, Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) (tesis de Maestría), XIII + 114 p.

Rouget M, Cowling RM, Lombard AT, Knight AT, Kerley GIH. 2006. Designing large-scale conservation corridors for pattern and process. Conservation Biology 20(2): 549-561.

Sánchez-Azofeifa GA, Harris RC, Skole DL. 2001. Deforestation in Costa Rica: a quantitative analysis using remote sensing imagery. Biotropica 22(3): 378-384.

Sanderson J, Da Fonseca GAB, Galindo-Leal C, Alger K, Inchausty VH, Morrison K, Rylands A. 2006. Escaping the minimalist trap: design and implementation of large-scale biodiversity corridors. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 620-648.

Santos T, Telleria JL. 2006. Pérdida y fragmentación de hábitat: efecto sobre la conservación de las especies. Ecosistemas 15(2): 3-12.

Saunders DA, Hobbs RJ, Margules CR. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5: 18-32.

Saura S, Pascual Hortal L. 2007a. A new habitat availability index to integrate connectivity in landscape conservation planning: comparison with existing indices and application to a case study. Landscape and Urban Planning 83(2-3): 91-103.

Saura S, Pascual Hortal L. 2007b. Conefor Sensinode 2.2 user's manual: software for quantifying the importance of habitat patches for maintaining landscape connectivity through graphs and habitat availability indices. Universidad de Lleida, España, 55 p.

Schedlbauer JL, Finegan B, Kavannagh KL. 2007. Rain forest structure at forest-pasture edges in northeastern Costa Rica. Biotropica 39(5): 578-584.

Schelhas J, Greenberg R. (eds.). 1996. Forest patches in tropical landscape. Washington, DC, Island Press, XXXVI, 426 p.

Schelhas J., Sánchez-Azofeifa G.A. 2006. Post-frontier forest change adjacent to Braulio Carrillo National Park, Costa Rica. Human Ecology 34(3), 407-431.

Sesnie SE, Finegan B, Gessler PE, Ramos Z. 2009. Landscape-scale environmental and floristic variation in Costa Rican old-growth rain forest remnants. Biotropica 41(1): 16-26.

Simberloff D, Cox J. 1987. Consequences and costs of conservation corridors. Conservation Biology 1: 63-71.

Simberloff D, Farr JA, Cox J, Mehlman DW. 1992. Movement corridors: conservation bargains or poor investments? Conservation Biology 6: 493-504.

Soulé ME. 1991. Theory and strategy. In Hudson E. (ed.). Landscape linkages and biodiversity. Washington, DC, Island Press, 91-104.

Taylor PD, Fahrig L, With KA. 2006. Landscape connectivity: a return to the basics. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 29-43.

Taylor PD, Fahrig L, Henein K, Merriam G. 1993. Connectivity is a vital element of landscape structure. Oikos 68: 571-573.

Tewksbury JJ, Garner L, Garner S, Lloyd JD, Saab V, Martin TE. 2006. Tests of landscape influence: nest predation and brood parasitism in fragmented ecosystems. Ecology 87(3): 759-768.

Theobald DM. 2006. Exploring the functional connectivity of landscapes using landscape networks. In Crooks KR, Sanjayan M. (eds.). Connectivity conservation. Cambridge, UK, Cambridge University Press, 416-443.

Thomas CD, Franco Aldina MA, Hill JK. 2006. Range retractions and extinction in the face of climate warming. Trends in Ecology & Evolution 21(8): 415-416.

Urban DL, Keitt T. 2001. Landscape connectivity: a graph-theoretic perspective. Ecology 82: 1205-1218.

Vamosi JC, Knight TM, Steets JA, Mazer SJ, Burd M, Ashman TL. 2006. Pollination decays in biodiversity hotspots. Proceedings of the National Academy of Sciences 103(4): 956-961.

Villard MA, Trzcinski MK, Merriam G. 1999. Fragmentation effects on forest birds: relative influence of woodland cover and configuration on landscape occupancy. Conservation Biology 13: 774-783.

Walker R, Craighead L. 1997. Least-cost path corridor analysis: analyzing wildlife movement corridors in Montana using GIS. Proceedings of the 1997 ESRI User's Conference. San Diego, CA, Environmental Systems Research Institute (ESRI), s. p.

Willis EO. 1974. Populations and local extinctions of birds on Barra Colorado Island, Panama. Ecological Monographs 44: 153-169.

With KA. 2002. Using percolation theory to assess landscape connectivity and effects of habitat fragmentation. In Gutzwiller KG. (ed.). Applying landscape ecology in biological conservation. New York, Springer, 105-130.

Worboys GL. 2010. The connectivity conservation imperative. In Worboys GL, Francis WL, Lockwood M. (eds.). Connectivity conservation management. London, Earthscan, 3-21.

9.4 Threatened species potentially found in the Border Biological Corridor Mixed Wildlife Refuge and Maquenque Mixed Wildlife Refuge.

Main sources: UICN 1999, Elizondo 1997, McDade (ed.) 1994, Janzen (ed.) 1983, MARENA 2001.

MAMMALS:

	Species	Common Name	Status	*Cause*	*Altitude*
1	*Metachirus nudicaudatus*	zorricí	Less common	PH	0 - 1200
2	*Myrmecophaga tridactyla*	oso caballo	endangered	PH/CI	0 - 800
3	*Cyclopes didactylus*	serafín de platanar	threatened	PH	0 - 1500
4	Choloepus hoffmanni	perezoso de dos dedos	reduced	PH/CI	0 - 3300
5	Bradypus variegatus	perezoso tres dedos	threatened	PH/CI	0 - 2400
6	*Cabassous centralis*	armadillo zopilote	threatened	PH	0 - 1800
7	Cyttarops alecto	murciélago	rare		0 - 100
8	Micronycteris daviesi	murciélago	very rare		0 - 300
9	*Vampyrum spectrum*	murciélago	threatened	PH/CI	0 - 1500
10	*Ectophylla alba*	murciélago blanco	less common		0 - 700
11	*Thyroptera discifera*	murciélago	rare		0 - 300
12	*Cebus capucinus*	mono carablanca	reduced	PH/CI	0 - 2000
13	*Alouatta palliata*	mono congo	endangered	PH/CI	0 - 2500
14	*Ateles geoffroyi*	mono colorado	threatened	PH/CI	0 - 2200
15	Sciurus deppei	ardilla	threatened	PH	0 - 2800
16	Dasyprocta punctata	guatusa	threatened	PH/CI	0 - 2400
17	Agouti paca	tepezcuintle	threatened	PH/CI	0 - 2000
18	Bassariscus sumichrasti	cacomistle, olingo	threatened	PH	0 - 2700
19	*Bassaricyon gabbii*	martilla	threatened	PH	0 - 1700
20	*Galictis vittata*	grisón	threatened	PH	0 - 1500
21	*Lutra longicaudis*	nutría	endangered	PH/CI	0 - 3000
22	*Puma concolor*	puma	threatened	PH/CI	0 - 3500
23	*Panthera onca*	jaguar	threatened	PH/CI	0 - 2000

	Species	Common Name	Status	*Cause*	*Altitude*
24	*Leopardus pardalis*	manigordo	threatened	PH/CI	0 - 3500
25	*Leopardus wiedii*	tigrillo	threatened	PH/CI	0 - 3000
26	*Herpailurus yaguarondi*	león breñero	threatened	PH/CI	0 - 2000
27	*Trichechus manatus*	manatí	endangered	PH/MA/CI	0 - 50
28	*Tapirus bairdii*	danta	threatened	PH/CI	0 - 3000
29	*Tayassu tajacu*	saíno	threatened	PH/CI	0 - 3000
30	*Tayassu pecari*	cariblanco	endangered	PH/CI	0 - 1900
31	*Odocoileus virginianus*	venado cola blanca	threatened	PH/CI	0 - 2600
32	*Mazama americana*	cabro de monte	threatened	PH/CI	0 - 2800

Source: Reid 1997.

BIRDS

	Species	Common Name	Status	*Cause*	*Altitude*
1	*Tinamus major*	gongolona	threatened	PH/CI	0 - 1700
2	*Crypturellus boucardi*	gongolona	threatened	PH	0 - 700
3	*Botaurus pinnatus*	puncus	threatened	PH	0 - 600
4	*Ixobrychus exilis*	mirasol	threatened	PH	0 - 1400
5	*Agamia agami*	garza pechicastaña	threatened	PH	0 - 300
6	*Jabiru mycteria*	galán sin ventura	endangered	PH/CO	0 - 200
7	*Mesembrinibis cayennensis*	coco negro	threatened	PH	0 - 200
8	*Ajaia ajaja*	pato cuchara	threatened	PH/CO	0 - 300
9	*Cairina moschata*	pato real	threatened	PH/CI	0 - 600
10	*Oxyura dominica*	pato enmascarado	threatened	PH	0 - 1200
11	*Sarcoramphus papa*	rey de zopilotes	threatened	PH	0 - 1200
12	*Chondrohierax uncinatus*	gavilán piquiganchudo	threatened	PH	0 - 1000
13	*Rostrhamus sociabilis*	gavilán caracolero	threatened	PH	0 - 500
14	*Geranospiza caerulescens*	gavilán ranero	threatened	PH	0 - 500
15	*Accipiter superciliosus*	camaleón	threatened	PH	0 - 1200

	Species	Common Name	Status	*Cause*	*Altitude*
16	*Leucopternis semiplumbea*	gavilán dorsiplomizo	threatened	PH	0 - 800
17	*Buteogallus urubitinga*	gavilán silbero	threatened	PH	0 - 1200
18	*Busarellus nigricollis*	gavilán pescador	threatened	PH	0 - 300
19	*Morphnus guianensis*	águila crestada	endangered	PH	0 - 800
20	*Harpia harpyja*	águila harpía	endangered	PH	0 - 2000
21	*Spizastur melanoleucus*	aguilillo blanco y negro	endangered	PH	0 - 3000
22	*Spizaetus ornatus*	aguilucho penachudo	threatened	PH	0 - 1500
23	*Spizaetus tyrannus*	aguilucho negro	threatened	PH	0 - 2000
24	*Daptrius americanus*	cacao	endangered	PH	0 - 1200
25	*Micrastur mirandollei*	halcón de monte	threatened	PH	0 - 800
26	*Falco peregrinus*	halcón peregrino	threatened	CO	0 - 1200
27	*Falco deiroleucus*	halcón pechirrufo	endangered	PH	0 - 1300
28	*Crax rubra*	pavón	threatened	PH/CI	0 - 1200
29	*Penelope purpurascens*	pava	threatened	PH/CI	0 - 1200
30	*Odontophorus melanotis*	chirrascuá	threatened	PH/CI	0 - 1000
31	*Rhynchortyx cinctus*	codorniz cariroja	threatened	PH	150 - 800
32	*Heliornis fulica*	pato cantil	endangered	PH	0 - 200
33	*Eurypyga helias*	sol y luna	threatened	PH	100 - 1200
34	*Columba speciosa*	torcaza	threatened	PH	0 - 1200
35	*Geotrygon violacea*	perdiz violácea	threatened	PH	0 - 800
36	*Geotrygon veraguensis*	paloma bigotiblanco	threatened	PH	0 - 900
37	*Ara ambiguus*	lapa verde	endangered	PH/CI	0 - 900
38	*Ara macao*	lapa roja	endangered	PH/CI	0 - 800
39	*Amazona autumnalis*	lora	threatened	PH/CI	0 - 800
40	*Amazona farinosa*	lora	threatened	PH/CI	0 - 500
41	*Neomorphus geoffroyi*	cuco hormiguero	rare	PH	0 - 900
42	*Lophostrix cristata*	lechuza	threatened	PH	0 - 1500

	Species	Common Name	Status	*Cause*	*Altitude*
43	*Trogon clathratus*	trogón	threatened	PH	90 - 1100
44	*Chloroceryle inda*	martín pescador	threatened	PH	0 - 300
45	*Jacamerops aurea*	jacamar grande	threatened	PH	0 - 500
46	*Carpodectes nitidus*	cotinga nivosa	threatened	PH	0 - 750
47	*Cephalopterus glabricollis*	pájaro sombrilla	threatened	PH	100 - 2000
48	*Piprites griseiceps*	saltarín cabecigris	threatened	PH	100 - 750
49	*Laniocera rufescens*	plañidera moteada	threatened	PH	0 - 700
50	*Aphanotriccus capitalis*	mosquerito	threatened	PH	0 - 1000
51	*Icterus mesomelas*	chorcha, chiltote	threatened	CI	0 - 1000
52	*Lanio leucothorax*	tangara piquiganchuda	threatened	PH	100 - 900

Source: Stiles *et al*. 1995, Stotz *et al*. 1996.

AMPHIBIANS

	Species	Common Name	Status	Cause	Altitude
1	*Dermophis parviceps*	solda con solda	threatened		100 - 1500
2	*Gymnopis multiplicata*	dos cabezas	threatened		0 - 1400
3	*Bolitoglossa colonnea*	salamandra	threatened		50 - 1000
4	*Oedipina alfaroi*	salamandra	threatened	E/PH	0 - 500
5	*Oedipina carablanca*	salamandra	threatened	E/PH	0 - 300
6	*Oedipina collaris*	salamandra	threatened		0 - 500
7	*Oedipina cyclocauda*	salamandra	threatened		0 - 800
8	*Bufo melanochloris*	sapo	threatened	E/PH	0 - 2000
9	*Centrolene ilex*	rana de vidrio	threatened	PH	0 - 800
10	*Centrolenella magna*	rana de vidrio	threatened	PH	50 - 800
11	*Cochranella spinosa*	rana de vidrio	threatened		0 - 600
12	*Dendrobates auratus*	sapo venenoso	threatened	PH/CI	0 - 800
13	*Dendrobates pumilio*	sapo venenoso	threatened	PH/CI	0 - 900

	Species	Common Name	Status	Cause	Altitude
14	*Phyllobates lugubris*	sapo venenoso	threatened	PH	0 - 650
15	*Agalychnis calcarifer*	rana de árbol	threatened	PH/CI	0 - 600
16	*Agalychnis saltator*	rana de árbol	threatened	PH/CI	0 - 70
17	*Anotheca spinosa*	rana coronada	threatened	PH	0 - 1200
18	*Hyla microcephala*	rana de árbol	threatened		0 - 1200
19	*Phyllomedusa lemur*	rana de árbol	threatened		60 - 1900
20	*Eleutherodactylus altae*	sapo, rana	threatened	E/PH	100 - 1200
21	*Eleutherodactylus biporcatus*	sapo, rana	threatened	PH	0 - 800
22	*Eleutherodactylus gollmeri*	sapo, rana	threatened		50 - 1500
23	*Eleutherodactylus mimus*	sapo, rana	threatened		15 - 900
24	*Eleutherodactylus noblei*	sapo, rana	threatened		0 - 1200
25	*Eleutherodactylus rugulosus*	sapo, rana	threatened		0 - 2370

Source: Leenders 2001.

REPTILES

	Species	Common Name	Status	Cause	Altitude
1	*Caiman cocrodilus*	caimán	reduced	PH/CI	0 - 200
2	*Crocodylus acutus*	cocodrilo	endangered	PH/CI	0 - 200
3	*Kinosternon angustipons*	tortuga candado	threatened	PH/CI	
4	*Chelydra serpentina*	Tortuga lagarto	endangered	PH	0 - 550
5	*Thecadactylus rapicauda*	gecko	threatened		0 - 200
6	*Iguana iguana*	iguana verde	threatened	PH/CI	0 - 800
7	*Norops carpenteri*	lagartija	threatened		40 - 1500
8	*Norops fungosus*	lagartija	threatened		0 - 500
9	*Norops lemurinus*	lagartija	threatened		0 - 800
10	*Norops pentaprion*	lagartija	threatened		0 - 800
11	*Norops sericeus*	lagartija	threatened		0 - 1300
12	*Dactyloa frenata*	lagartija	threatened		0 - 850

13	*Dactyloa insignis*	lagartija	threatened		0 - 1000
14	*Polychrus gutturosus*	lagartija	threatened		0 - 1800
15	*Ptychoglossus plicatus*	lagartija	threatened		0 - 700
16	*Lepidophyma reticulatum*	perro zompopo	threatened	E/PH	0 - 1300
17	*Celestus hylaeus*	lagartija	threatened	E/PH	0 - 700
18	*Boa constrictor*	boa, béquer	threatened	CI	0 - 900
19	*Corallus annulatus*	boa	threatened	CI	0 - 800
20	*Epicrates cenchria*	boa	threatened	CI	0 - 500
21	*Clelia clelia*	zopilota	threatened	CI	0 - 800
22	*Geophis ruthveni*	culebra de tierra	threatened	E/PH	0 - 300
23	*Sibon argus*	culebra	threatened	E/PH	0 - 900
24	*Trimetopon pliolepis*	culebra	threatened	E/PH	40 - 1700
25	*Trimetopon simile*	culebra	threatened	E/PH	100 - 800
26	*Trimetopon viquezi*	culebra	threatened	E/PH	100 - 800
27	*Ungaliophis panamensis*	culebra	threatened	PH	0 - 200

Source: Leenders 2001.

FISHES

	Species	Common Name	Status	Cause	Altitude
1	*Carcharhinus leucas*	tiburón toro	limited	CI/CO	
2	*Pristis perotteti*	pez sierra	limited	CI/CO	0 - 30
3	*Pristis pectinatus*	pez sierra	limited	CI/CO	0 - 30
4	*Centropomus undecimalis*	robalo	limited	CI	
5	*Atractosteus tropicus*	gaspar	endangered	CI/CO	
6	*Rivulus isthmensis*	olomina	threatened	PH/CO	0 - 1500
7	*Brachyrhaphis olomina*	olomina	less common	PH/CO	10 - 900
8	*Priapichtys annectens*	olomina	endemic	PH/CO	25 - 1270
9	*Agonostomus monticola*	tepemechín	threatened	CI/PH/CO	0 - 650
10	*Joturus pichardi*	bobo	less common	CI/PH/CO	0 - 600

Source: Bussing 1998.

TREES

	Species	Common Name	Status	Cause	Altitude
1	*Aspidosperma spruceanum*	amargo, caretigre	Limited		
2	*Tabebuia guayacan*	corteza, guayacán	threatened	PH	100 - 600
3	*Ceiba pentandra*	ceiba	threatened		50 - 300
4	*Copaifera aromatica*	camíbar	threatened	PH	0 - 350
5	*Cynometra retusa*	guapinol negro	very limited		0 - 150
6	*Prioria copaifera*	cativo	threatened	PH	0 - 150
7	*Sclerolobium costarricense*	tostado	endangered	PH	50 - 700
8	*Terminalia amazonia*	roble coral	threatened		30 - 300
9	*Terminalia oblonga*	surá, guayabón	threatened		20 - 400
10	*Dalbergia melanocardium*	bálsamo	threatened		100 - 900
11	*Dalbergia glomerata*	granadillo	threatened		0 - 500
12	*Dipteryx panamensis*	almendro	threatened		
13	*Dussia macroprophyllata*	sangregao	threatened	PH	0 - 600
14	*Hymenolobium mesoamericanum*	cola de pavo	endangered	PH	30 - 700
15	*Platymiscium pinnatum*	cachimbo, cristobal	endangered	PH	0 - 600
16	*Humiriastrum diguense*	chiricano alegre	threatened	PH	0 - 700
17	*Vantanea barbourii*	chiricano triste	threatened	PH	0 - 800
18	*Povedadaphne quadriporata*	ira rosa	rare		
19	*Couroupita guianensis*	bala de cañon	rare		
20	*Lecythis ampla*	olla de mono	threatened	PH	50 - 300
21	*Ruptiliocarpon caracolito*	caracolito	threatened		200 - 650
22	*Carapa guianensis*	caobilla	decreased		50 - 250
23	*Cedrela fissilis*	cedro real	endangered	PH	50 - 500
24	*Cedrela odorata*	cedro amargo	threatened	PH	0 - 1200
25	*Trichilia pittieri*		rare		
26	*Minquartia guianensis*	manú	threatened	PH	0 - 500

	Species	Common Name	Status	Cause	Altitude
27	*Podocarpus guatemalensis*	cipresillo, pinillo	endangered	PH	50 - 1500
28	*Elaeoluma glabrescens*	carey	threatened		50 - 300
29	*Sideroxylon capiri*	danto amarillo	threatened	PH	0 - 900
30	*Christiana africana*	piedra	rare		
31	*Vochysia allenii*	botarrama	rare	E/PH	
32	*Qualea paraensis*	areno	threatened	PH	100 - 850

Source: Jiménez 1993, Jiménez 1997, Sánchez-Vindas *et al*. 1987, Quesada *et al*. 1997, Holdridge *et al*. 1997, Zamora *et al*. 2000.

Status:

E: endemic

Cause:

PH: habitat loss

CI: intensive hunting or over fishing

CO: pollution

Plant species predominat in wetlands of the Northern zone of Costa Rica

Common Name [1]	***Scientific***		***Common Name***	***Scientific***
Sota de Suampo	Zygia confusa		Yolillo	Raphia taedigera.
Roble Coral*	Terminalia Amazonia		Gavilán	Pentaclethra macroloba
Gavilán	Pentaclethra macroloba		Botarrama*	Vochysia ferruginea
Fruta Dorada	Virola sebifera		Tabacón de Suampo	Cespedesia macrophylla
Pejibayito	Maranthes panamensis		Baco	Couma macrocarpa
Repollito	Eschweilera costaricensis		Cedro María	Calophyllum brasiliense
Repollito	Eschweilera panamensis		Maquengue Amargo	Socratea exorrhiza
Botarrama*	Vochysia ferruginea	***Laguna Canacas***	Labios de puta	Psychotria poeppigiana
Mouriri	Mouriri gleasoniana		Capiruto	(Melastomataceae)
Maquengue Amargo	Socratea exorrhiza		Fruta dorada	Virola koschnyi

1 * Species with some degree of vulnerability.

Nace blanco	Byrsonima crispa		Palma Conga	Welfia regia
Miconia	Miconia punctata		Tamarindo	Dialum guianense
Vismia	Vismia macrophylla		Baco	Brosimum utile.
Sapotillo	Pouteria durlandii		Cuero de sapo	Licania affinis
Nancite blanco	Byrsonima crispa		Ferdinandusa	Ferdinandusa panamensis
Casearia	Casearia arborea		Repollito	Eschweilera costaricensis
Ferdinandusa	Ferdinandusa panamensis		Mouriri	Mouriri gleasoniana
Botarrama*	Vochysia ferruginea		Maquengue Amargo	Socratea exorrhiza
Laurel Muñeco	Cordia bicolor		Carey*	Elaeoluma glabrescens
Gallinazo	Jacaranda copaia		Gavilán	Pentaclethra macroloba
Vainillo	Sthryphnodendron microstachyum		Repollito	Eschweilera panamensis
Guabo	Inga alba		Licania hoja dorada	Licania belloi
Gavilán	Pentaclethra macroloba		Aceituno	Simarouba amara
Sota de Suampo	Zygia confusa		Gallinazo	Jacaranda copaia
Baco	Brosimum utile.		Manga Larga	Laetia procera
Aceituno	Simarouba amara		Cucaracho Chiricano*	Vantanea barbourii
Croton	Croton smithianus		Maquenque	Swartzia maquenqueana
Colpachi	Croton schiedeanus		Botarrama*	Vochysia ferruginea
Melina	Gmelina arborea		Miconia plata	Miconia sp.
Manga Larga	Laetia procera	Laguna Tambor	Miconia	Miconia punctata
Cedrillo	Tapirira guianensis		Hirtella	Hirtella media
Alibertia	Alibertia atlantica		Cedrillo	Tapirira guianensis

9.5 Limited and threatened species to be used in local reforestation.

Tree species from the study area, considered limited according to several authors, suggested to be considered in reforestation programs to protect riversides along Route 1856.

SPECIES	COMMON NAME
Aspidosperma spruceanum	amargo, caretigre
Balizia elegans	ajillo
Carapa guianensis	caobilla
Cedrela fissilis	cedro real
Cedrela odorata	cedro amargo
Ceiba pentandra	ceiba
Copaifera aromatica	camíbar
Couroupita guianensis	bala de cañón
Cynometra retusa	guapinol negro
Dalbergia melanocardium	bálsamo
Dipteryx panamensis	almendro
Dussia macroprophyllata	sangregao
Elaeoluma glabrescens	carey
Enterolobium schomburgkii	guanacaste blanco
Gordonia fruticosa	campano blanco
Guettarda turrialbana	??
Hymenolobium mesoamericanum	cola de pavo
Ilex skutchii	plomillo, campano
Lecointea amazonica	costilla de danto
Lecythis ampla	olla de mono
Licania affinis	cuero de sapo
Manilkara zapota	níspero chicle
Micropholis melinoniana	zapotillo
Minquartia guianensis	manú
Ormosia velutina	nene
Podocarpus guatemalensis	cipresillo, pinillo
Prioria copaifera	cativo
Pseudolmedia spuria	ojochillo
Qualea paraensis	areno
Ruptiliocarpon caracolito	caracolito

Sclerolobium costarricense	tostado
Sideroxylon capiri	danto amarillo
Tabebuia guayacan	corteza, guayacán
Talauma gloriensis	magnolia
Terminalia amazonia	roble coral
Terminalia oblonga	surá, guayabón
Vantanea barbourii	chiricano triste
Vatairea lundellii	cocobolo, amargo
Vochysia allenii	botarrama
Williamodendron glaucophyllum	aguacatillo

Source: CCT, 2013.

9.6 Tree species observed in the area of Las Crucitas, San Carlos.

LISTA TOTAL DE LAS ESPECIES OBSERVADAS

Nombre científico	Familia	Nombre Vernáculo
Acalypha apodanthes	Euphorbiaceae	Fosforillo
Acalypha diversifolia	Euphorbiaceae	Fosforillo
Acidoton nicaraguensis	Euphorbiaceae	------
Allophylus psilospermus	Sapindaceae	Huesillo
Alseis hondurensis	Rubiaceae	------
Ampelocera macrocarpa	Ulmaceae	------
Amyris sp	Rutaceae	Manzana
Andira inermis	Papilionaceae	Almendro de montaña, Carne asada, Areno, Arenillo
Angostura nicaraguiensis	Rutaceae	------
Apeiba membranacea	Tiliaceae	Botijo, Peine de mico
Ardisia brenesii	Myrsinaceae	Tucuico
Aspidosperma myristicifolium	Apocynaceae	Amargo, Caretigre
Aspidosperma spruceanum	Apocynaceae	Manglillo, Vara alta, Pintura de indio
Astrocaryum standleyanum	Arecaceae	Chontadura
Atalea butyracea	Arecaceae	Palma real, Corozo
Balizia elegans	Mimosaceae	Ajillo
Borojoa atlantica	Rubiaceae	Guayaba de mico
Bourreria huanita	Boraginaceae	------
Brosimum guianense	Moraceae	Ojoche, Ojochillo
Brosimum lactescens	Moraceae	Ojoche, Ojochillo
Brosimum alicastrum	Moraceae	Ojoche
Bunchosia macrophylla	Malpighiaceae	Cerezo
Bursera simaruba	Burseraceae	Jiñocuabe, Jiñote, Indio desnudo
Byrsonima crassifolia	Malpighiaceae	Nancite
Byrsonima crispa	Malpighiaceae	Nancite de montaña
Calatola costaricensis	Icacinaceae	Palo de papa, Palo azul, Coquito
Callicarpa acuminata	Verbenaceae	------
Calophyllum brasiliense	Clusiaceae	Cedro María, María
Calyptranthes sp	Myrtaceae	Murta, Guayabillo
Carapa guianensis	Meliaceae	Cedro Macho, Caobilla, Cedro bateo, Cedro Cóbano
Casearia commersoniana	Flacourtiaceae	Manga larga, Peipute
Casearia arborea	Flacourtiaceae	Manga larga
Castilla elastica	Moraceae	Hule, Palo de hule
Cecropia obtusifolia	Cecropiaceae	Guarumo
Cecropia insignis	Cecropiaceae	Guarumo
Cedrela odorata	Meliaceae	Cedro amargo
Ceiba pentandra	Bombacaceae	Ceiba

Cespedesia macrophylla	Ochnaceae	Tabacón, Espavel colorado
Cestrum panamense	Solanaceae	Zorrillo
Chrysophyllum colombianum	Sapotaceae	Caimito de montaña
Cinnamomun cinnamomifolium	Lauraceae	Aguacatillo
Clarisia mexicana	Moraceae	Ojochillo
Clarisia biflora	Moraceae	Ojochillo
Clusia spp	Clusiaceae	Copey
Coccoloba tuerckheimii	Polygonaceae	Piedra, Papaturro
Cojoba valerioi	Mimosaceae	Lorito
Colubrina spinosa	Rhamnaceae	------
Compsoneura sprucei	Myristicaceae	Fruta dorada
Conceveiba pleiostemona	Euphorbiaceae	Algodón, Pilón blanco, Chayotillo
Conostegia xalapensis	Melastomataceae	Lengua de gato, Mariquita
Cordia cymosa	Boraginaceae	Muñeco
Cordia spinescens	Boraginaceae	------
Cordia bicolor	Boraginaceae	Muñeco
Cordia alliodora	Boraginaceae	Laurel
Couma macrocarpa	Apocynaceae	Leche de vaca, Baco
Croton smithianus	Euphorbiaceae	Algodoncillo, Targuá
Croton schiedianus	Euphorbiaceae	Colpachí
Croton bilbergianus	Euphorbiaceae	Targuá
Cupania guatemalensis	Sapindaceae	Huesillo
Cupania glabra	Sapindaceae	Huesillo
Cyathea sp	Pteridophyta	Rabo de mico, Helecho arborescente
Cymbopetalum costaricense	Annonaceae	Anonillo
Cynometra retusa	Caesalpiniaceae	------
Dalbergia melanocardium	Papilionaceae	Bálsamo, Cristóbal
Dendropanax arboreus	Araliaceae	Fosforillo, Palomo
Dialium guianense	Caesalpiniaceae	Tamarindo de montaña, Tamarindo, Alfeñique
Drypetes brownii	Euphorbiaceae	-----
Dussia cuscatlanica	Papilonaceae	Targuayugo, Sandregao, Paleta
Dussia macroprophyllata	Papilonaceae	Targuayugo, Sandregao, Paleta
Dypterix panamensis	Papilionaceae	Almendro, Almendrón, Almendro de montaña
Elaeoluma glabrescens	Sapotaceae	Carey
Enterolobium schomburgkii	Mimosaceae	Guanacastillo, Guanacaste blanco
Erythrina cochleata	Papilionaceae	Poró
Erythroxylum macrophyllum	Erythroxylaceae	-----
Eschweilera costaricensis	Lecythidaceae	Repollito
Eugenia oerstedeana	Myrtaceae	Murta
Eugenia monticola	Myrtaceae	Murta
Eugenia glandulosopunctata	Myrtaceae	Murta
Euterpe macrospadix	Arecaceae	Palmito mantequilla
Faramea spp	Rubiaceae	Azulillo, Cafecillo

Ferdinandusa panamensis	Rubiaceae	------
Ficus crassivenosa	Moraceae	Higuerón, Chilamate
Ficus involuta	Moraceae	Higuerón, Chilamate
Ficus insipida	Moraceae	Higuerón, Chilamate
Ficus tonduzii	Moraceae	Higuerón, Chilamate
Ficus colubrinae	Moraceae	Higuerón
Ficus citrifolia	Moraceae	Higuerón
Ficus brevibracteata	Moraceae	Higuerón
Galipea granulosa	Rutaceae	Culebro
Garcinia madruno	Clusiaceae	Jorco
Garcinia intermedia	Clusiaceae	Jorco
Genipa americana	Rubiaceae	Guaitil, Tapaculo
Gliricidia sepium	Papilionaceae	Madero negro, Madre de cacao
Goethalsia meiantha	Tiliaceae	Guácimo blanco
Gordonia fruticosa	Theaceae	Campano, Campano blanco, Ira chiricano, Campano chile
Guarea pterorrhachis	Meliaceae	Cocora, Ocora
Guarea grandifolia	Meliaceae	Cóbano, Cedro Cóbano
Guarea bullata	Meliaceae	Ocora, Pocora
Guatteria inuncta	Annonaceae	Anonillo
Guatteria amplifolia	Annonaceae	Anonillo
Guettarda turrialbana	Rubiaceae	-----
Gymnanthes riparia	Euphorbiaceae	-----
Hampea appendiculata	Bombacaceae	Burío
Heisteria sp	Olacaceae	Chupeta
Hernandia didymantha	Hernandiaceae	Zopilote
Herrania purpurea	Sterculiaceae	Cacao de mico
Hippotis albiflora	Rubiaceae	-----
Hyeronima alchorneoides	Euphorbiaceae	Pilón, Zapatero
Hyeronima oblonga	Euphorbiaceae	Pilón, Zapatero, Nancitón
Hymenolobium mesoamericanum	Papilionaceae	Cola de Pavo
Ilex skutchii	Aquifoliaceae	Campano, Plomillo,Campano blanco
Inga alba	Mimosaceae	Guabo colorado
Inga thibaudiana	Mimosaceae	Guabo
Inga stenophylla	Mimosaceae	Guabillo
Inga tonduzii	Mimosaceae	Guabo mechudo
Inga densiflora	Mimosaceae	Caite, Guabo salado
Inga leiocalycina	Mimosaceae	Guabo
Iriartea deltoidea	Arecaceae	Palmito
Isertia laevis	Rubiaceae	-----
Jacaranda copaia	Bignoniaceae	Gallinazo, Jacaranda
Jacaratia spinosa	Caricaceae	Papayillo de venado
Lacmellea panamensis	Apocynaceae	Lagarto negro, Lagarto
Laetia procera	Flacourtiaceae	Manga larga, Plomo, Amarillón
Lecointea amazonica	Papilionaceae	Costilla de danto

Lecythis ampla	Lecythidaceae	Jícaro, Olla de mono
Licania affinis	Chrysobalanaceae	Cuero de sapo
Licania belloi	Chrysobalanaceae	Alcornoque
Lonchocarpus "camibar"	Papilionaceae	Camibar
Lonchocarpus unifoliatus	Papilionaceae	Chaperno
Luehea seemannii	Tiliaceae	Guácimo colorado, Guácimo macho
Lunania mexicana	Flacourtiaceae	-----
Mabea occidentalis	Euphorbiaceae	Lechillo
Machaerium seemannii	Papilionaceae	Sangrillo
Malvaviscus arboreus	Malvaceae	Amapolilla
Manilkara sapota	Sapotaceae	Níspero chicle, Níspero
Maquira costaricana	Moraceae	Ojochillo
Meliosma sp	Sabiaceae	-----
Miconia aeruginosa	Melastomataceae	Lengua de vaca
Miconia argentea	Melastomataceae	Lengua de vaca
Micropholis melinoniana	Sapotaceae	Zapotillo, Caimito
Minquartia guianensis	Olacaceae	Manú, Palo de Piedra, Manú negro
Mosquitoxylum jamaicense	Anacardiaceae	Cirrí, Cirrí colorado
Mouriri gleasoniana	Melastomataceae	Murta
Myrcia splendens	Myrtaceae	Murta
Naucleopsis naga	Moraceae	Quina
Nectandra valeriana	Lauraceae	Quizarrá
Nectandra spp	Lauraceae	Quizarrá
Nectandra mollifolia	Lauraceae	Quizarrá
Nectandra salicifolia	Lauraceae	Quizarrá
Ochroma pyramidale	Bombacaceae	Balso, Balsa
Ocotea spp	Lauraceae	Ira rosa
Ocotea atirrensis	Lauraceae	Ira
Ormosia velutina	Papilionaceae	Nene, Nene carita, Nene panza negra
Otoba novogranatensis	Myristicaceae	Fruta dorada, Hoja dorada
Pachira aquatica	Bombacaceae	Poponjoche, Ira de montaña
Palicourea guianensis	Rubiaceae	-----
Parinari excelsa	Chrysobalanaceae	Turrú, Pejibaye
Parmentiera edulis	Bignoniaceae	Cuajilote
Pausandra trianae	Euphorbiaceae	-----
Pentaclethra macroloba	Mimosaceae	Gavilán, Gavilán Quebracho
Pentagonia wendlandii	Rubiaceae	Tabacón
Pimenta guatemalensis	Myrtaceae	Jamaica
Piper auritum	Piperaceae	Anisillo, Anís, Hoja de estrella
Podocarpus guatemalensis	Podocarpaceae	Pinillo, Ciprecillo
Posoqueria grandiflora	Rubiaceae	Guayaba de mico
Pourouma minor	Cecropiaceae	Chumico
Pourouma bicolor	Cecropiaceae	Chumico, Guarumo de montaña
Pouteria spp	Sapotaceae	Zapote
Pouteria subrotata	Sapotaceae	Zapote

Pouteria calistophylla	Sapotaceae	Zapote
Pouteria lucentifolia	Sapotaceae	Zapote
Pouteria torta	Sapotaceae	Zapotillo
Protium sp	Burseraceae	Canfín, Alcanfor, Copalillo
Protium pittieri	Burseraceae	Canfín, Alcanfor, Copalillo
Pseudolmedia spuria	Moraceae	Ojochillo
Psidium guajava	Myrtaceae	Guayabo
Psychotria elata	Rubiaceae	Labios ardientes
Psychotria tomentosa	Rubiaceae	Labios ardientes
Pterocarpus hayesii	Papilionaceae	Sangrillo, Sangregao
Qualea paraensis	Vochysiaceae	Masicarán, Areno
Quararibea asterolepis	Bombacaceae	Garrocho, Guácimo molenillo
Quassia amara	Simaroubaceae	Hombre grande
Quiina amazonica	Quiinaceae	Quina
Rinorea sylvatica	Violaceae	-----
Rollinia pittieri	Annonaceae	Anonillo, Candelo, Anón
Rondeletia buddleoides	Rubiaceae	-----
Ryania speciosa	Flacourtiaceae	-----
Sacoglottis trichogyna	Humiriaceae	Campano, Titor, Danto plomillo
Salacia sp	Hippocreateaceae	-----
Sapium glandulosum	Euphorbiaceae	Yos
Sapranthus sp	Annonaceae	Anonillo
Sclerolobium costaricense	Papilionaceae	Tostado
Senna papillosa	Caesalpiniaceae	Candelillo
Simarouba amara	Simaroubaceae	Aceituno
Siparuna spp	Monimiaceae	-----
Sloanea sp	Elaeocarpaceae	Terciopelo
Sloanea fragrans	Elaeocarpaceae	Paleta, Terciopelo
Socratea exorrhiza	Arecaceae	Palmito amargo
Solanum rugosum	Solanaceae	Zorrillo
Solanum jamaicense	Solanaceae	Zorrillo
Sorocea trophoides	Moraceae	Ojochillo
Sorocea pubivena	Moraceae	Ojochillo
Spirothea rosea	Bombacaceae	Ceiba
Spondias mombin	Anacardiaceae	Jobo
Sterculia costaricana	Sterculiaceae	Panamá
Sterculia recordiana	Sterculiaceae	Panamá
Stryphnodendrum microstachyum	Mimosaceae	Vainillo, Gallinazo
Swartzia simplex	Papilionaceae	-----
Symphonia globulifera	Clusiaceae	Cerillo
Tabebuia rosea	Bignoniaceae	Roble de sabana
Tabebuia guayacan	Bignoniaceae	Corteza, Guayacán
Tabernaemontana arborea	Apocynaceae	Cachitor
Talauma gloriensis	Magnoliaceae	Magnolia
Talisia nervosa	Sapindaceae	Mamón de montaña

Tapirira myriantha	Anacardiaceae	Cirrí, Cirrí colorado
Terminalia bucidioides	Combretaceae	Escobo, Escobo negro, Guayabón negro
Terminalia amazonia	Combretaceae	Roble coral, Amarillón, Guayabo de charco
Tetragastris panamensis	Anacardiaceae	Canfín
Ticorea unifoliata	Rutaceae	-----
Trema micrantha	Ulmaceae	Capulín blanco
Trichilia sp	Meliaceae	-----
Trichilia septentrionalis	Meliaceae	------
Trichospermum galeotti	Tiliaceae	Guácimo blanco, Capulín
Trophis mexicana	Moraceae	Ojochillo
Turpinia occidentalis	Staphyliaceae	-----
Unonopsis sp	Annonaceae	Anonillo
Vantanea barbourii	Humiriaceae	Chiricano triste, Chiricano, Ira chiricano
Vernonia patens	Asteraceae	Tuete
Virola koschnyi	Myristicaceae	Fruta dorada
Virola sebifera	Myristicaceae	Fruta dorada
Virola surinamensis	Myristicaceae	Fruta dorada
Vismia macrophylla	Clusiaceae	Achiotillo
Vismia ferruginea	Clusiaceae	Achiotillo
Vitex cooperi	Verbenaceae	Manú, Manú plátano
Vochysia guatemalensis	Vochysiaceae	Chancho, Chancho blanco, Cebo, Mayo
Vochysia megalophylla	Vochysiaceae	Mayo, Ira de agua
Vochysia allenii	Vochysiaceae	Mayo, Mayo blanco
Vochysia ferruginea	Vochysiaceae	Botarrama, Mayo colorado
Warszewiczia coccinea	Rubiaceae	Pastora
Welfia georgii	Arecaceae	-----
Williamodendron glaucophyllum	Lauraceae	Aguacatillo
Xylopia sericophylla	Annonaceae	Anonillo, Manga larga, Flaco
Xylopia bocatorena	Annonaceae	Anonillo
Xylopia frutescens	Annonaceae	Anonillo
Zanthoxylon kellermannii	Rutaceae	Lagarto, Lagarto negro
Zanthoxylon melanostictum	Rutaceae	Lagarto
Zanthoxylon ekmannii	Rutaceae	Lagarto, Lagarto amarillo
Zygia brenesii	Mimosaceae	Lorito
Zygia longifolia	Mimosaceae	Sotacaballo, Azote de caballo

Source: Centro Científico Tropical. 1996. Inventario de Vegetación en el Proyecto Minero Cerro Crucitas. Placer Dome de Costa Rica S.A. (Dendrólogos Sanchez Pablo y Poveda Luis).

9.7 Taxa richness and abundance of individuals of aquatic macroinvertebrates collected at study sites along Route 1856, Juan Rafael Mora Porras, July - August, 2013. Upstream (Abj) and downstream (Arb) of the road. (*) less common taxa or with limited distribution in the country.

Taxon	Sitio 1		Sitio 2		Sitio 3		Sitio 4		Sitio 5		Sitio 6		Sitio 7		Sitio 8		Sitio 9		Sitio 10	
	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb
Coleoptera																				
Dytiscidae																				
Derovatellus															1					
Vatellus																1				
Gen. Indet.		1													1	1				
Elmidae																				
Cylloepus									1											
Heterelmis									2											
Hexacylloepus									1											
Macrelmis									1					1						
Microcylloepus						1														
Hydrophilidae																				
Gen. Indet.	2						2						1							
Limnichidae																				
*Limnichites**	8		1												3		8	1		1
Psephenidae																				
Dicranoselaphus *																			1	
Ptilodactylidae																				
Anchytarsus									1				1							
Scirtidae																				
Gen. Indet.		1					2													
Staphylinidae																				
Gen. Indet.																				1
Lampyridae *																				
Gen. Indet.																1				
Dryopidae																				
Elmoparnus												1	1							
Diptera																				
Ceratopogonidae																				
Bezzia			1							1										
Probezzia			1															1		
Chironomidae																				
Chironomini	9	4	2			2	1										1			

Taxon	Sitio 1		Sitio 2		Sitio 3		Sitio 4		Sitio 5		Sitio 6		Sitio 7		Sitio 8		Sitio 9		Sitio 10	
	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb
Orthocladiinae			1		2	1										1				
Tanypodinae			2	2	1	10				1					2			2		
Tanytarsini			2		1	4								1				1		
Gen. Indet.			1		1	5											1			
Tipulidae																				
Hexatoma													1							
Gen. Indet.														1						
Culicidae																				
Aedes																			1	
Anopheles		1																		
Culex			1																	
Gen. Indet.															1					
Simuliidae																				
Simulium					13	1			32		1	1		1						
Ephemeroptera																				
Baetidae																				
Americabaetis		2			49	10	13		2	2					1			3		
Apobaetis	1	1	1	1		3									1		2	1	2	2
Callibaetis			1			1														
Cloeodes		1			1	1	1			2										
Fallceon					1												1			
Caenidae																				
Caenis	2	4	6	2	2	13														
Leptophlebiidae																				
Farrodes		5		1	11	6			15	17		2	3	1				1		
Terpides *		7				1				22					2				1	
Tikuna *																2				
*Ulmeritoides**	6	1	1	1				3		1						4		1		
Heptageniidae																				
*Maccaffertium**										3										
Leptohyphidae																				
Cabecar *										4										
Epiphrades		1			3	7	9								1	1				
Leptohyphes					3				1	1										
Tricorythodes	3	7	2	1	1	5	1		2	9					4	1				
Vacupernius *		1																		
Hemiptera																				
Belostomatidae																				
Belostoma							1													

Taxon	Sitio 1		Sitio 2		Sitio 3		Sitio 4		Sitio 5		Sitio 6		Sitio 7		Sitio 8		Sitio 9		Sitio 10	
	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb
Gen. Indet.							2													
Gerridae																				
Brachymetra albinervis								1		1										
Potamobates													1							
Potamobates unidentatus											2	3		1						
*Rheumatobates bergrothi**																1	1			
Tachygerris												2								
Telmatometra					1			1											1	
*Telmatometra withei**							1													
Gen. Indet.	1	1	1				3	3	1						1		7		7	6
Corixidae																				
Tenagobia							1									1	1			
Hydrometridae																				
Hydrometra				1																
Nepidae																				
*Ranatra**	1																			
Notonectidae																				
*Martarega**	3		1				2										6		25	
Gen. Indet.	2	3	7	6											2		34		27	16
Veliidae																				
Microvelia																1	1			1
Rhagovelia				1	14		5		3	1	4	2	2	4			2	9	1	
*Stridulivelia**												3								
Odonata																				
Calopterygidae																				
Hetaerina							5		2	1										
Coenagrionidae																				
Acanthagrion						3	1			1										
Argia						19	1	1		2										
Megapodagrionidae																				
Heteragrion		1								1										
Protoneuridae																				
*Neoneura**	2	4	2			3	2	1							1			2		
Gen. Indet.																			1	
Platystictidae																				
*Palaemnema**											1			4						

Taxon	Sitio 1		Sitio 2		Sitio 3		Sitio 4		Sitio 5		Sitio 6		Sitio 7		Sitio 8		Sitio 9		Sitio 10	
	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb
Polythoridae *																				
Gen. Indet.													1							
Gomphidae																				
Agriogomphus *										1										
Epigomphus		1								1			1							
Erpetogomphus																1				
*Perigomphus**														2						
Gen. Indet.													1							
Libellulidae																				
*Zenithoptera**						1														
Gen. Indet.		1		2		2			1							3		1	2	
Corduliidae																				
Neocordulia *												1								
Fam. Indet.																				
Gen. Indet.					2	1				1										

Taxon	Sitio 1		Sitio 2		Sitio 3		Sitio 4		Sitio 5		Sitio 6		Sitio 7		Sitio 8		Sitio 9		Sitio 10	
	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb
Trichoptera																				
Glossosomatidae																				
Protoptila										1										
Helicopsychidae																				
Helicopsyche										2										
Hydropsychidae																				
Leptonema											1	5	2	8						
*Macronema**										1										
Smicridea					7				1	1		1		2						
Leptoceridae																				
Nectopsyche		4								3	1		1		1					
Oecetis			1		2															
Polycentropodidae																				
Cernotina *						5														
Calamoceratidae																				
Phylloicus																2				
Plecoptera																				
Perlidae																				
Anacroneuria									6		1	2	2	3						
Megaloptera																				
Corydalidae																				

Taxon	Sitio 1		Sitio 2		Sitio 3		Sitio 4		Sitio 5		Sitio 6		Sitio 7		Sitio 8		Sitio 9		Sitio 10	
	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb
Corydalus												2		1						
Lepidoptera																				
Pyralidae																				
Gen. Indet.																			1	1
Dictyoptera																				
Blaberidae																				
Gen. Indet.								1												
Trombidiformes																				
Fam. Indet.																				
Gen. Indet.			6	3	2	2	5								1					
Haplotaxida																				
Haplotaxidae																				
Gen. Indet.	2		1								2			1	1					
Naididae																				
Gen. Indet.						1														
Rhynchobdellida																				
Glossiphoniidae																				
Haementeria				1																
Fam. Indet.														1						
Tricladida																				
Planariidae																				
Gen. Indet.					1				1											1
Architaenioglossa																				
Ampullariidae																				
Gen. Indet.																			1	
Basommatophora																				
Lymnaeidae																				
Gen. Indet.			1			12				1										
Physidae																				
Gen. Indet.				1																
Planorbidae																				
Gen. Indet.						2														
Neotaenioglossa																				
Hydrobiidae																				
Gen. Indet.		1																		
Sorbeoconcha																				
Thiaridae																				
Gen. Indet.						3														
Decapoda																				
Palaemonidae																				
Macrobrachium					1								2	2						

Taxon	Sitio 1		Sitio 2		Sitio 3		Sitio 4		Sitio 5		Sitio 6		Sitio 7		Sitio 8		Sitio 9		Sitio 10	
	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb
Pseudothelphusidae																				
Gen. Indet.													1							

Taxon	Sitio 1		Sitio 2		Sitio 3		Sitio 4		Sitio 5		Sitio 6		Sitio 7		Sitio 8		Sitio 9		Sitio 10	
	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb	Abj	Arb
Isopoda																				
Fam. Indet.																				
Gen. Indet.																				1
Ostracoda																				
Fam. Indet.																				
Gen. Indet.						1														
Total de individuos	42	53	43	23	119	126	58	11	73	82	13	25	21	34	24	21	65	23	71	30
Riqueza de Taxa	12	22	20	13	19	26	17	6	17	25	8	12	14	16	15	13	10	11	11	9